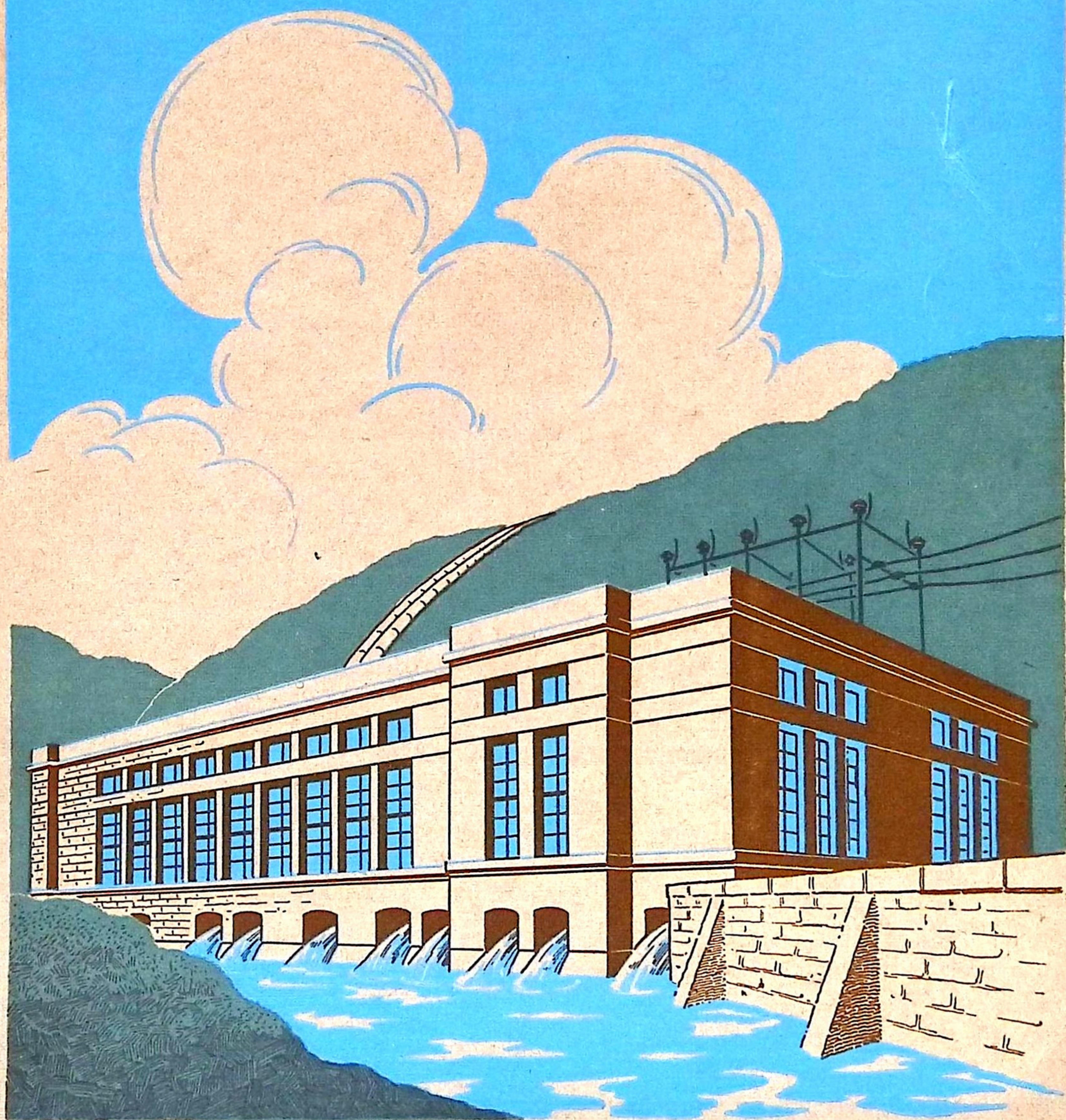


Alternating-Current Waterwheel Generators



Alternating-Current Waterwheel Generators



Circular 1536-A

June, 1919

Westinghouse Electric & Manufacturing Co.
East Pittsburgh, Pa.

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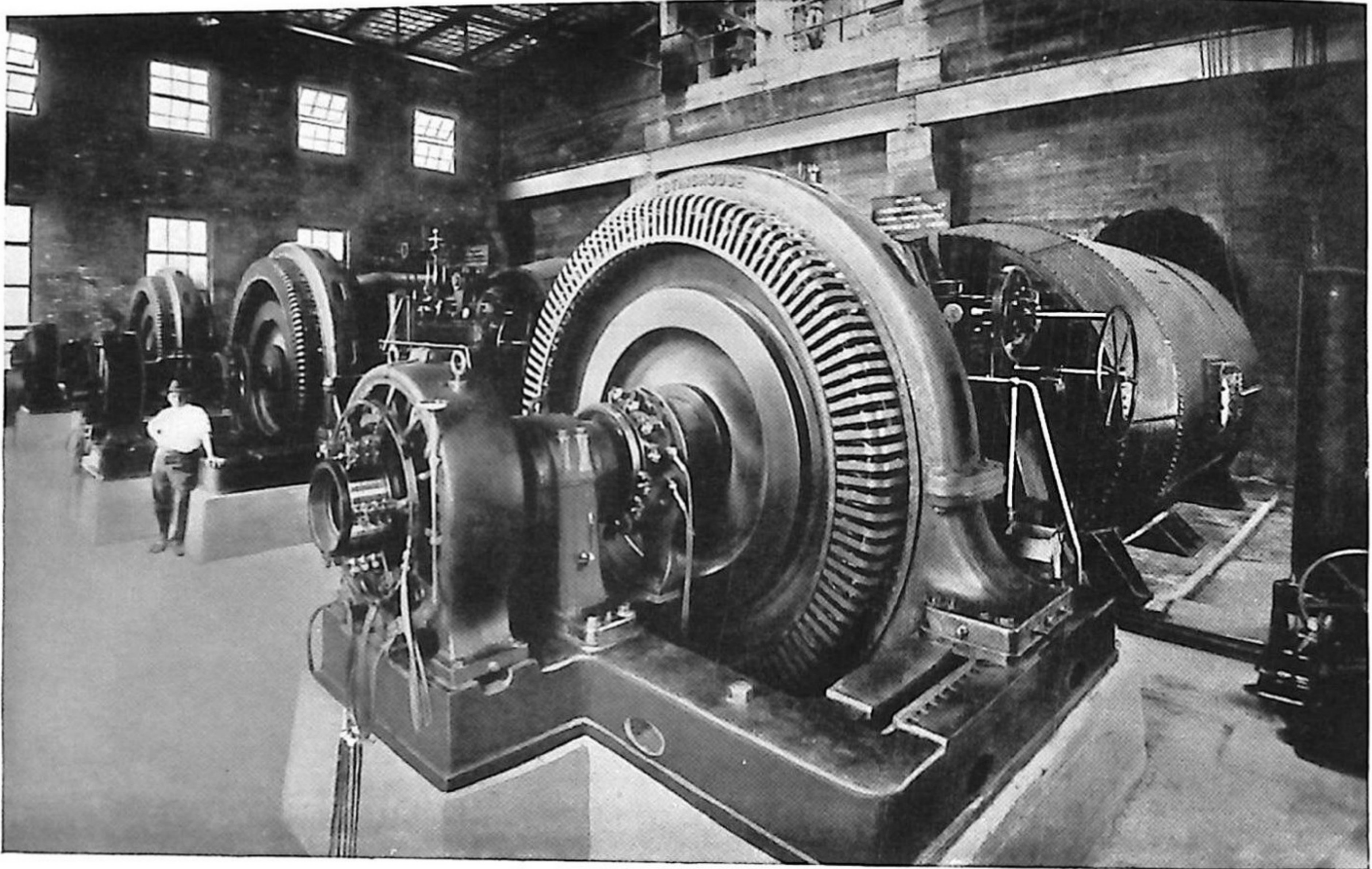
Foreword

THE water power resources of our country are estimated at sixty million horse power. More than 85 per cent of this is still undeveloped.

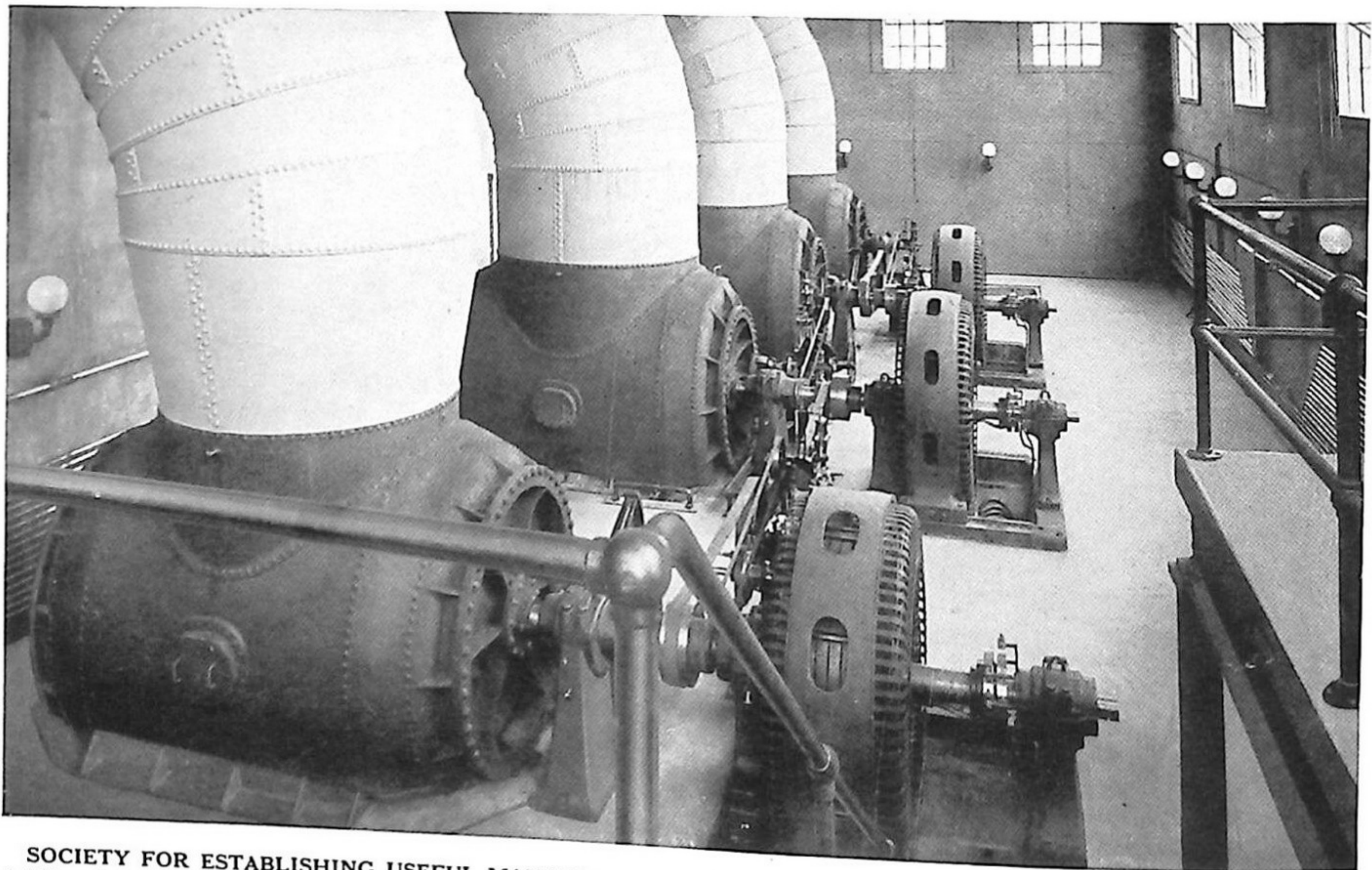
The generation of electricity by water power dates back less than thirty years. In this same short period of time the electrical industry has grown from an experimental, little understood art, to the enormous proportions of today, absolutely essential to our present welfare and our future progress.

The pioneer in the hydroelectric field grew with the electrical industry, and he has proven waterpower development both economically and financially sound. The investor of today has the experiences of earlier enterprises to guide him, and profits by them.

Waterwheel Generators

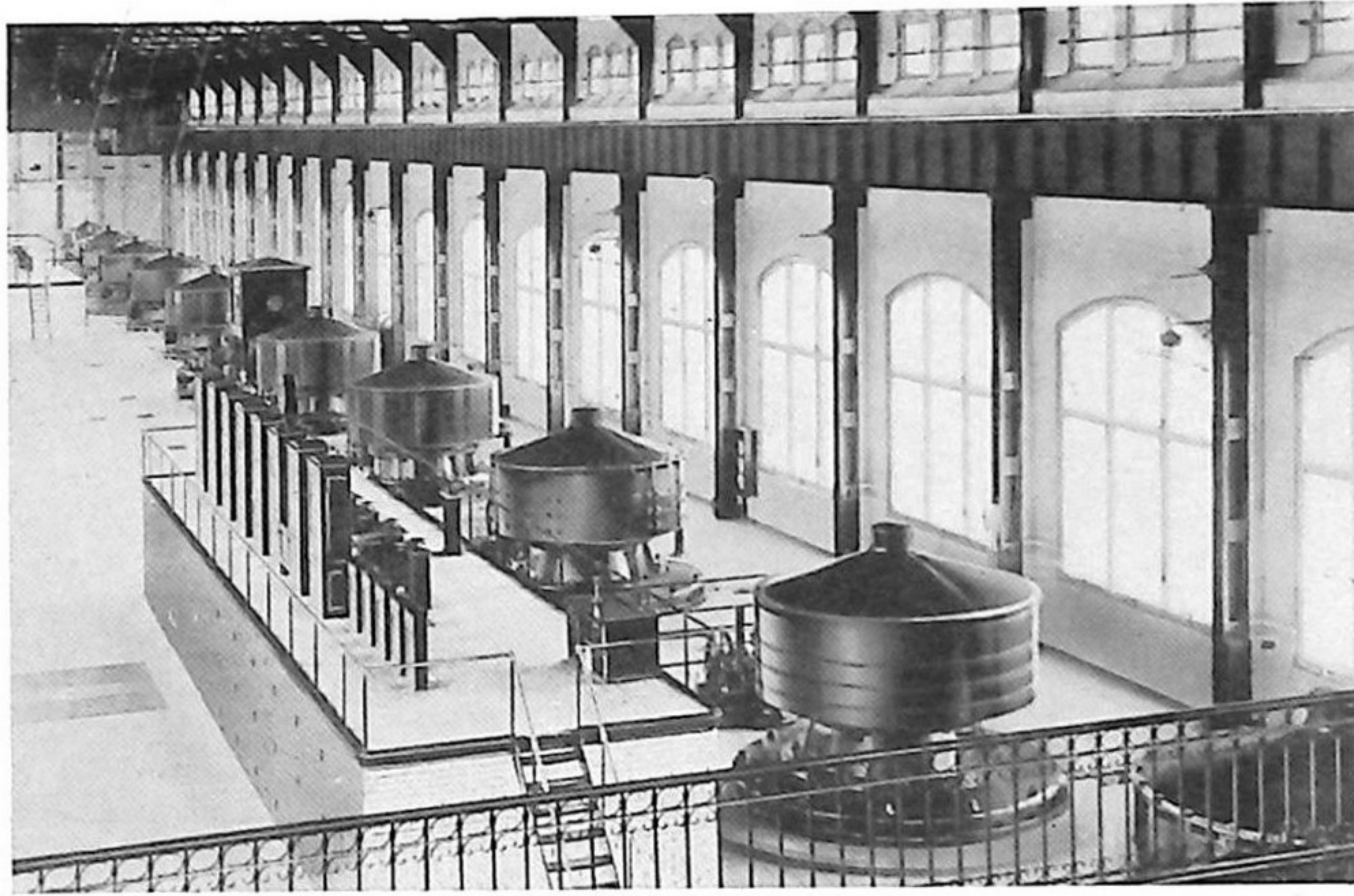


PENINSULAR POWER CO. PLANT AT TWIN FALLS, MICH., houses five 1,250 kva., 257 rpm. Westinghouse Generators, supplying mining and power load. Generating voltage, 6,600. Transmission lines, 66,000 Volts.



SOCIETY FOR ESTABLISHING USEFUL MANUFACTURES, PATERSON, N. J. Plant on Passaic River houses three 1,250 and one 850 kva. Westinghouse Generators, and supplies general manufacturing load. Head is 67 feet. Exciters are driven by separate waterwheels.

Alternating-Current Waterwheel Generators



FIRST "HYDRO" PLANT IN AMERICA was built in 1895 at Niagara Falls, New York.
It houses ten 3,750 kva. units which are still doing service.

Requirements

HYDRAULIC developments may vary in size from a hundred to a hundred thousand or more kilowatts. A few small investors can easily finance the former, the latter requires many hundreds. The power output of the small plant may be fully utilized by a dozen power users; the large development numbers its users by the thousand.

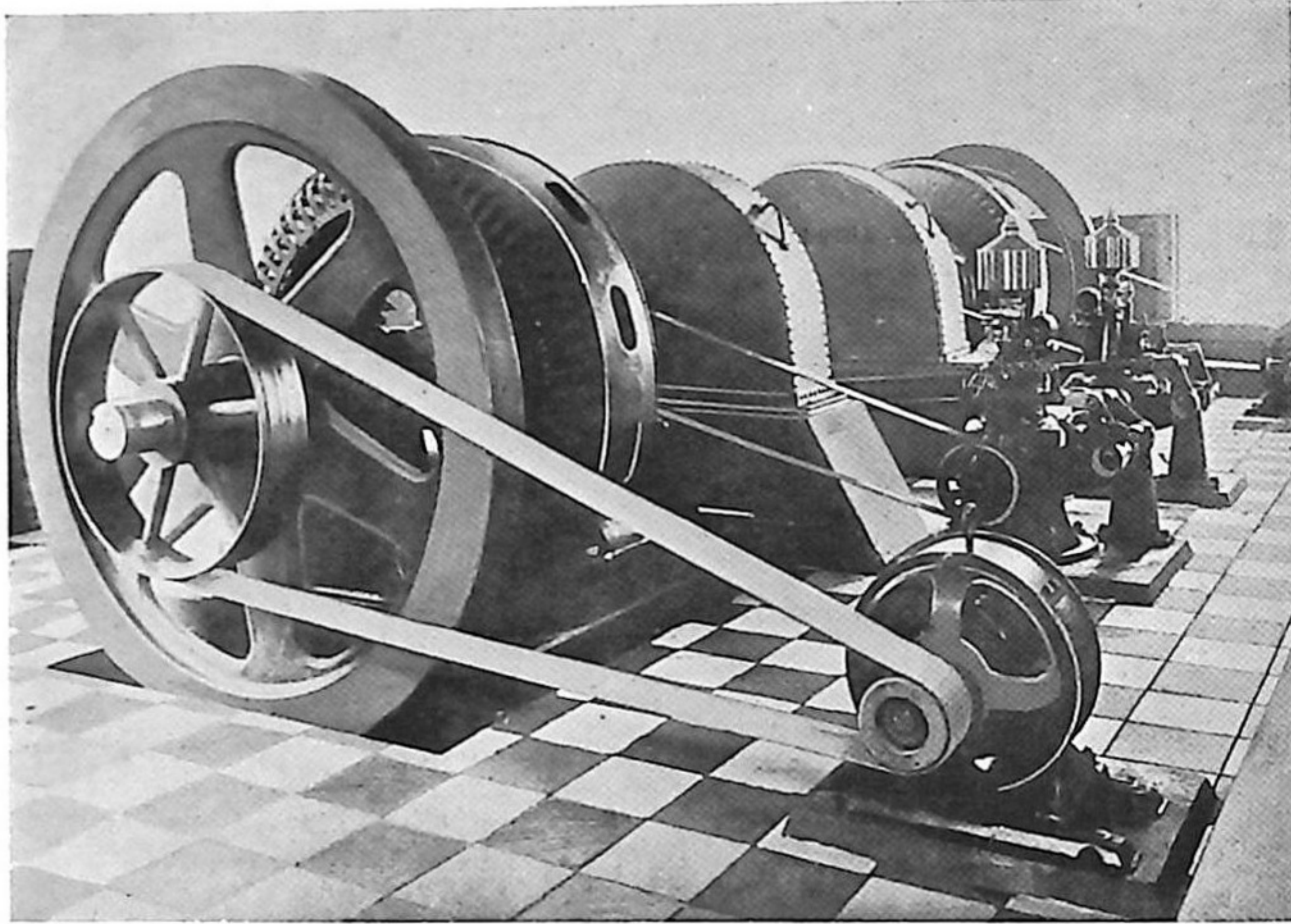
Granted sound engineering and financial management, both enterprises are entitled to a reasonable profit; both groups of consumers expect, and in fact demand, equally reliable service. All must rely on the character of the apparatus installed in the power plants.

Westinghouse waterwheel generators have become a standard for comparison. They are universally recognized as a product of the best quality, and merit this recognition because of the economical, reliable service which they give.

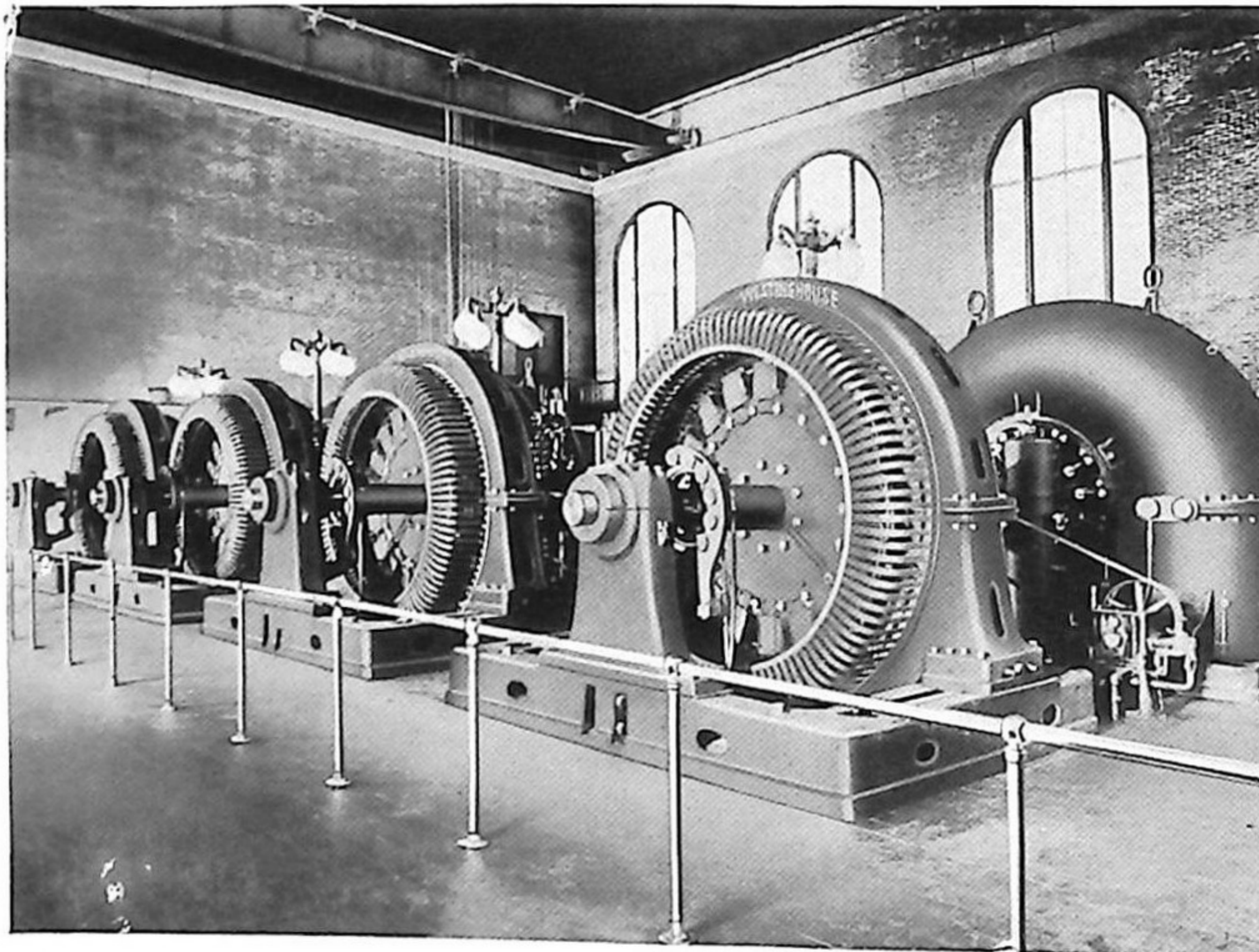
The Westinghouse machine of the future must, if that is possible, be even more serviceable, for the nature and variety of the industries dependent on it will be larger than ever before.

To all machines, great and small, is given the full benefit of our twenty-five years of experience. All are most carefully designed and all materials and workmanship are of the highest character.

Waterwheel Generators

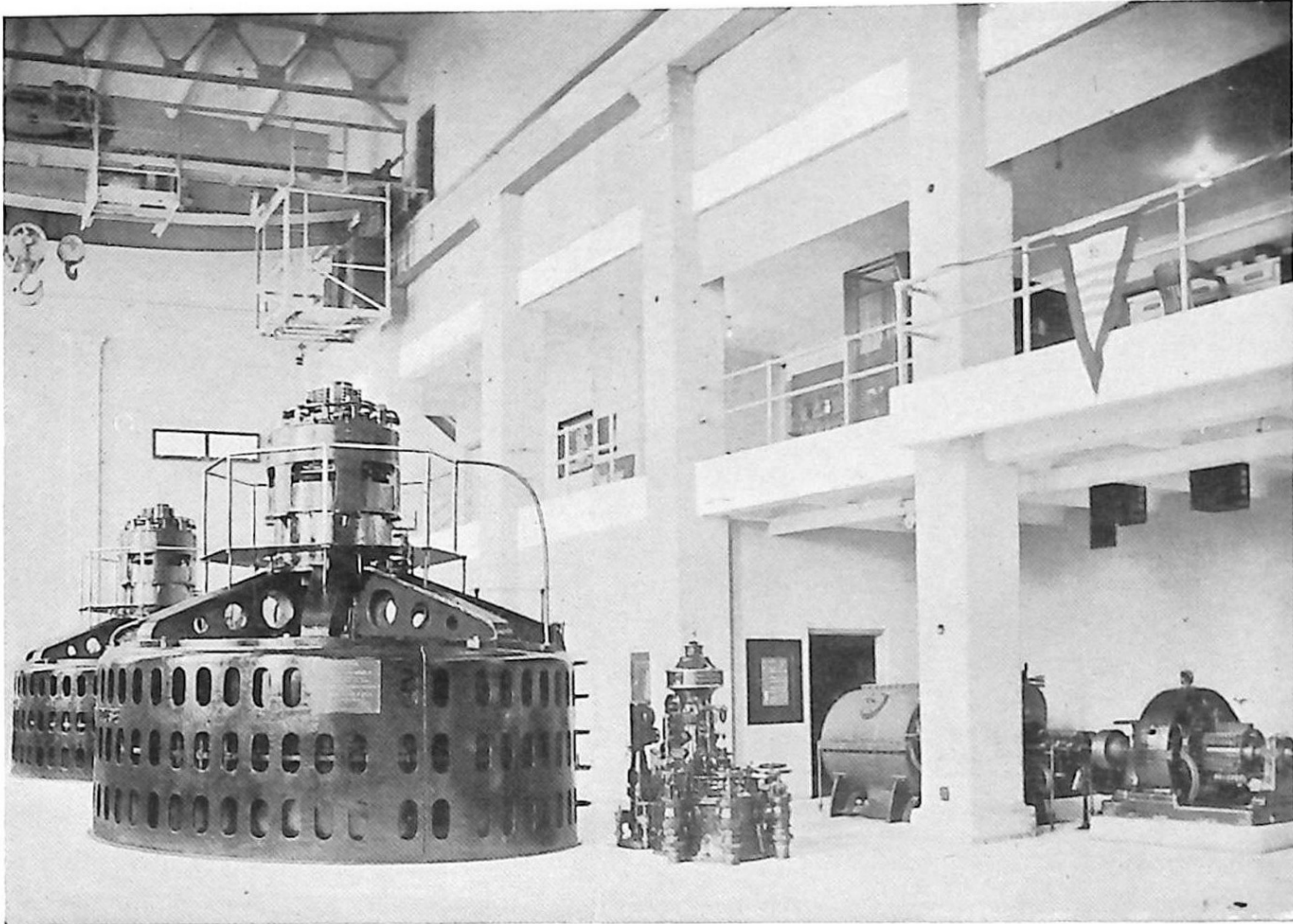


BUFFALO MFG. COMPANY, BUFFALO, WYOMING. Two 250 kva. horizontal Generators operating at a speed of 300 rpm., with external flywheels, and with belted exciters, driven from pulleys mounted on main shafts.



PLANT AT CLINTON, MASS., utilizing some power from Boston's water supply and generating at 13,800 volts to feed into general power system of that locality. Units operate under head of 90 feet and at 400 rpm. Each generator has a capacity of 1,000 kva.

Waterwheel Generators



RUMFORD FALLS POWER COMPANY, RUMFORD, MAINE. This view shows the two vertical Westinghouse Generators, of 8,000 kva. capacity each, installed in the recently completed addition to this company's power house which is now the largest hydro-electric plant in Maine. With two 4,000 kva. horizontal Westinghouse Generators previously installed, the generator capacity aggregates 24,000 kva. The addition comprises a large part of the construction of a new plant which will include 8,000 kva. vertical generators, operating under a head of 100 feet and at 200 rpm. The generating and transmission voltage is 11,000. Formerly, practically all the power developed by this plant was used in the manufacture of pulp and paper but in recent years other industries have been attracted to Rumford and have been added to the pulp and paper industries as users of this power.

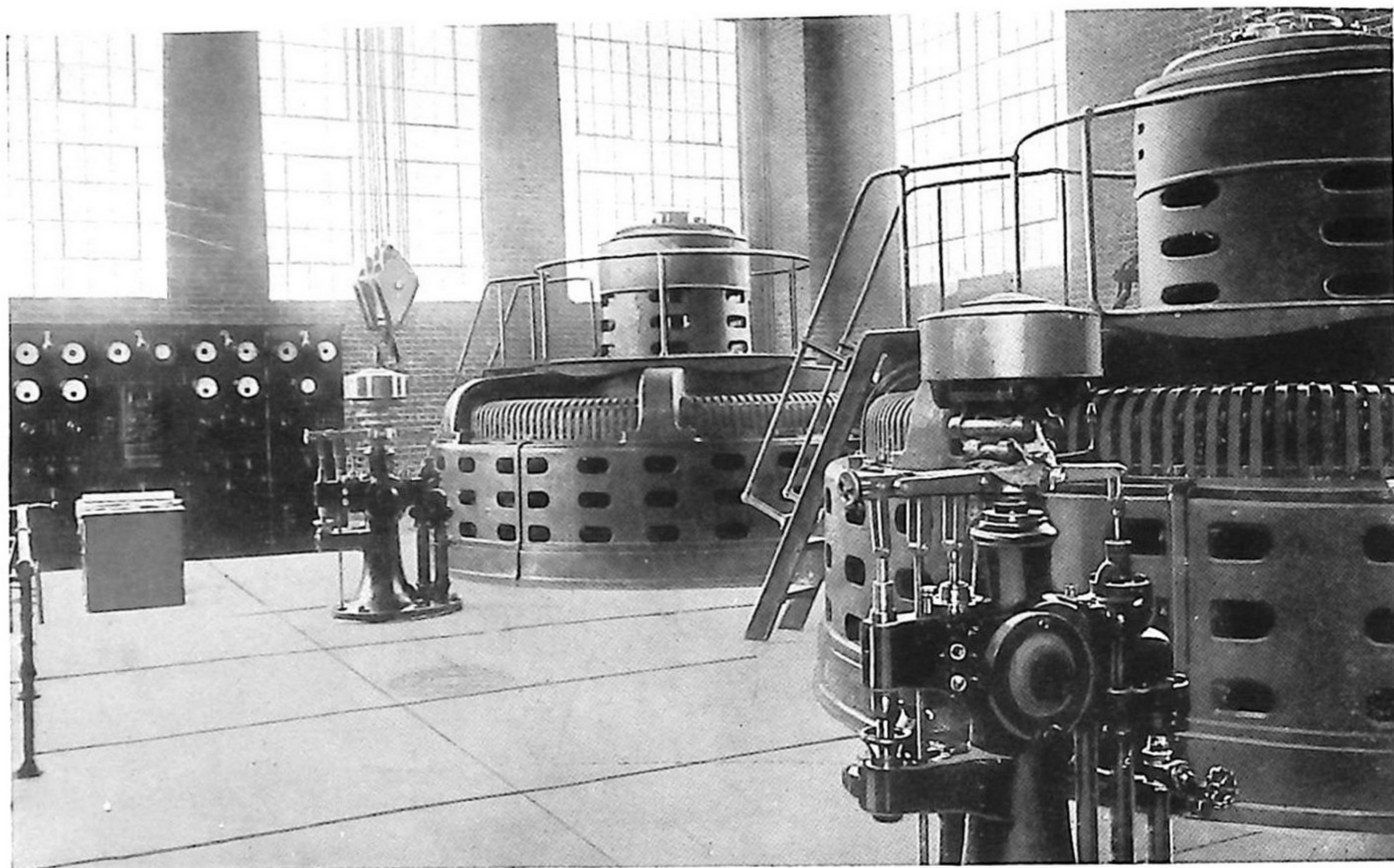
First Cost

THE electrical equipment in the "hydro" plant represents but a small percentage of the total development's cost. The amount of trouble, and the loss of revenue, that unreliable equipment can cause, is great.

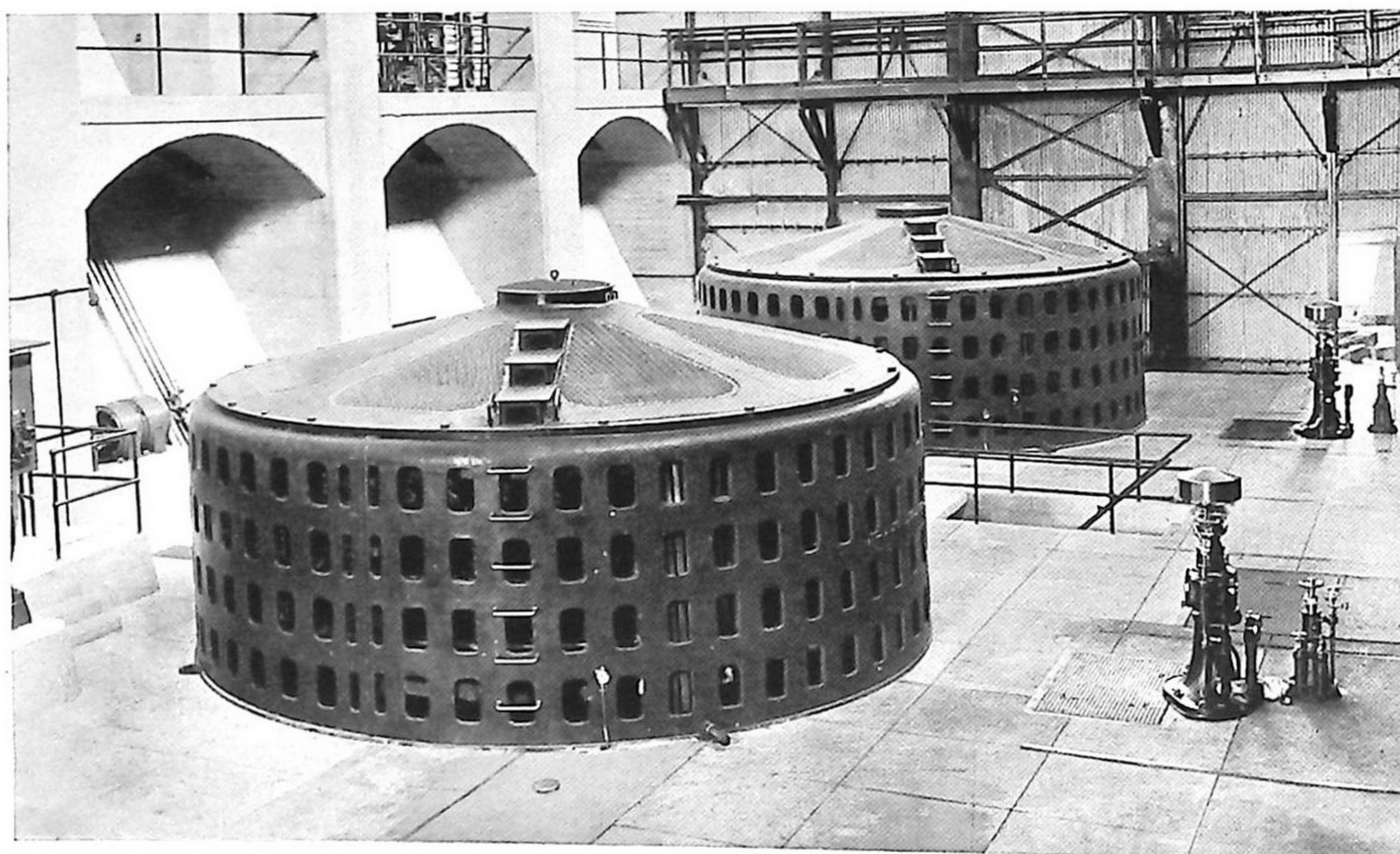
No electrical manufacturer can, given modern methods of competition, succeed, who spends money unnecessarily on his products. But neither manufacturer, nor purchaser, can risk trouble for the doubtful expedient of a slight saving in cost.

In the selecting and proportioning of materials, and in the manner and care of their assembly, Westinghouse designers never overlook the necessity of good "wearing qualities." At the same time, the vast amount of data and experience gained in building many hundred generators of widely varying capacities and speeds, is an invaluable asset insuring the purchaser of the best quality at reasonable cost.

Waterwheel Generators



NORTH CAROLINA ELECTRIC POWER CO., MARSHALL, N. C. Two 1,875 kva., 133 rpm. Generators. Hydraulic head, 40 Feet. Used for general power load. Generating voltage, 6,600. Transmission lines, 66,000 Volts.



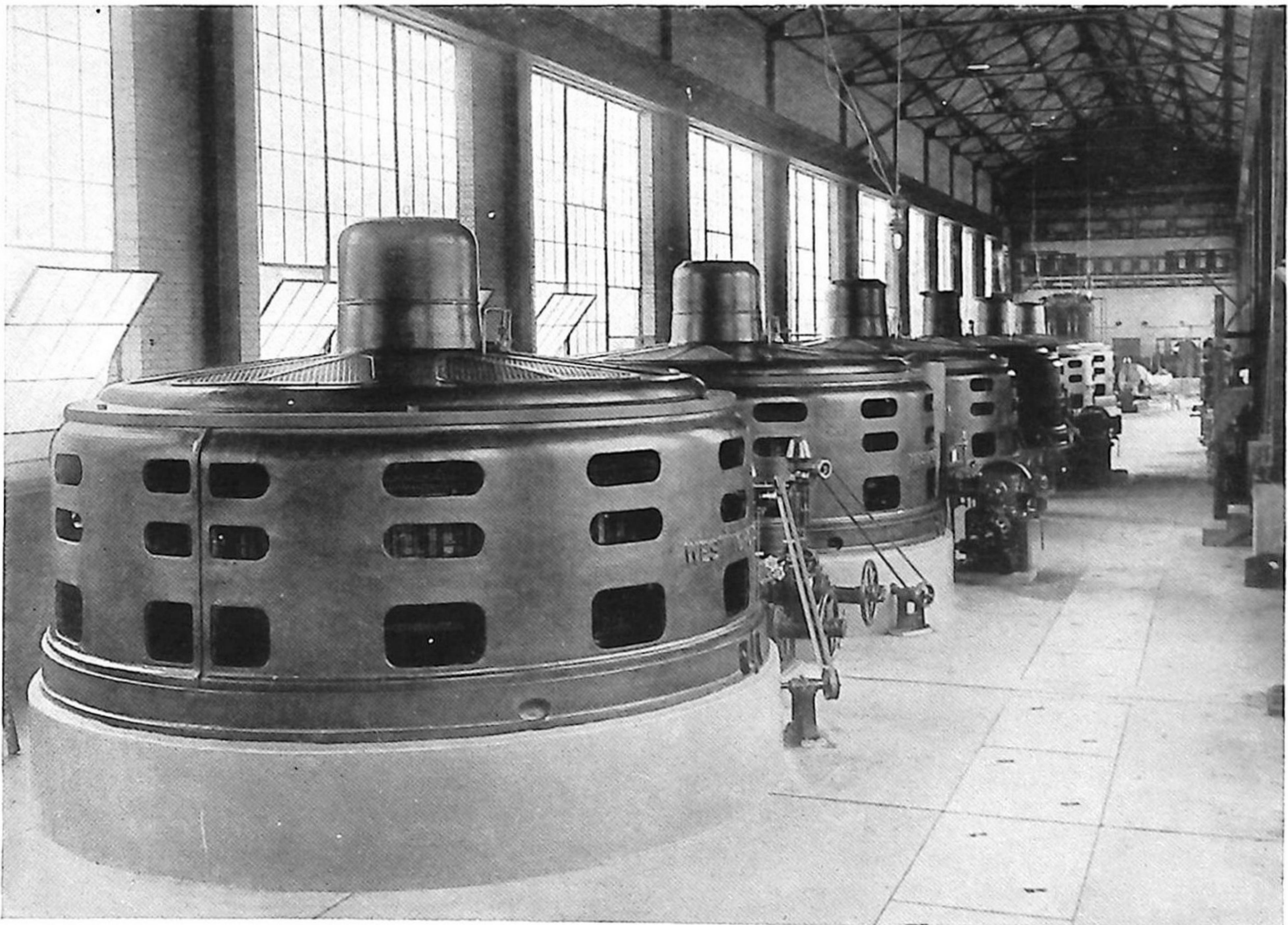
THE LARGEST "HYDRO" PLANT IN PENNSYLVANIA, AT HOLTWOOD, PA. Power is generated at 11,000 volts, stepped up to 70,000 volts and transmitted to Baltimore, Md. Hydraulic head is 55 feet. Last three units installed are Westinghouse, each 12,000 kva. in capacity, two operating at 116 rpm., one at 94 rpm.

Waterwheel Generators

Types

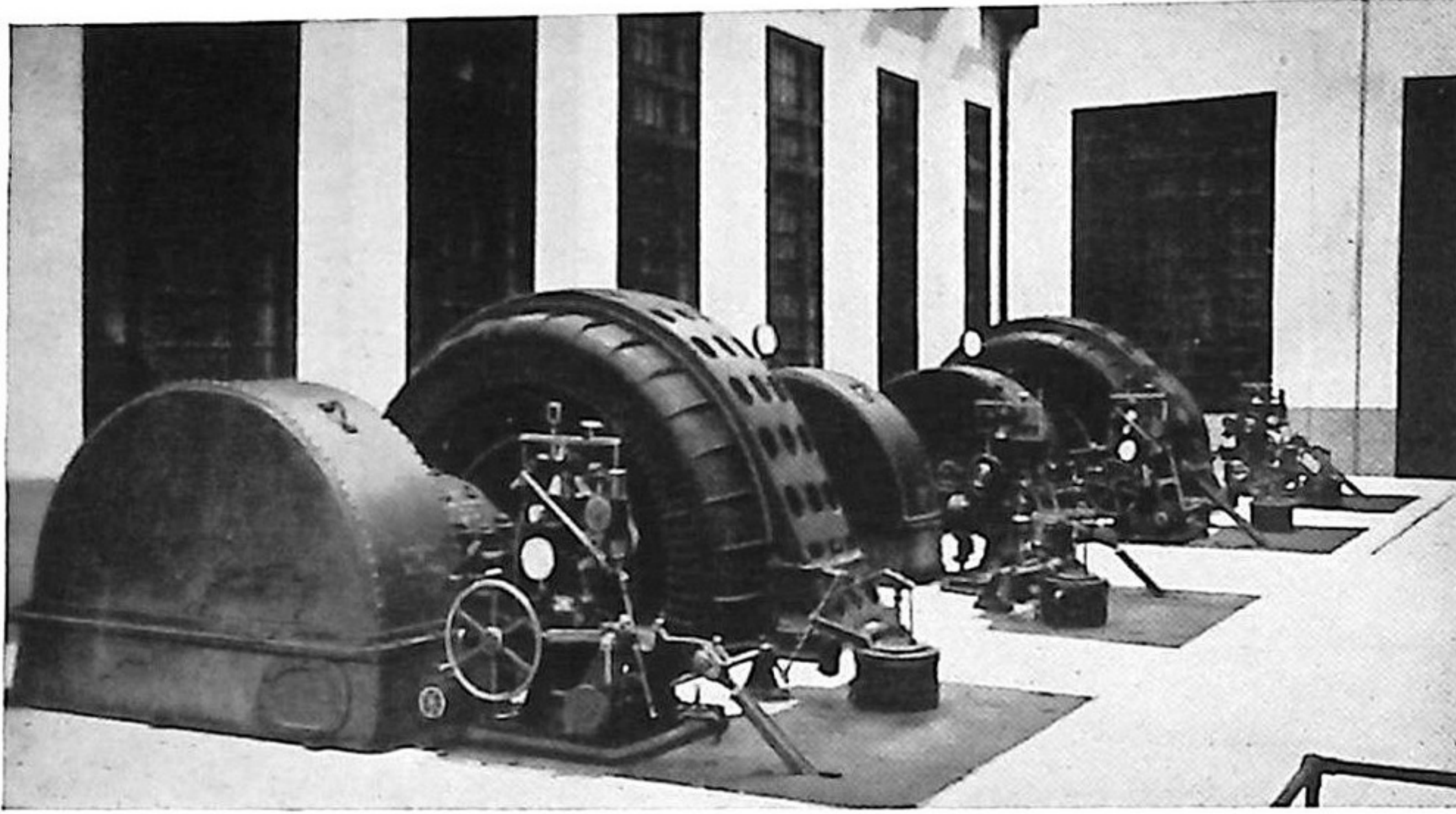
WESTINGHOUSE waterwheel generators have been built in capacities ranging from thirty to thirty thousand kilowatts, and two units, each of 45000 kva. capacity, are now building. The shaft connecting to the waterwheel may be either horizontal or vertical. And speeds vary almost as much as capacities if maximum economy under available hydraulic conditions is to be obtained.

Obviously no one type of construction covers such a range. Generators are therefore classified as of the horizontal or the vertical type, the latter now being used almost universally for relatively low head work. The success of the Kingsbury thrust bearing, manufactured and supplied by the Westinghouse Company on its vertical units, has played no small part in establishing the vertical type in favor.



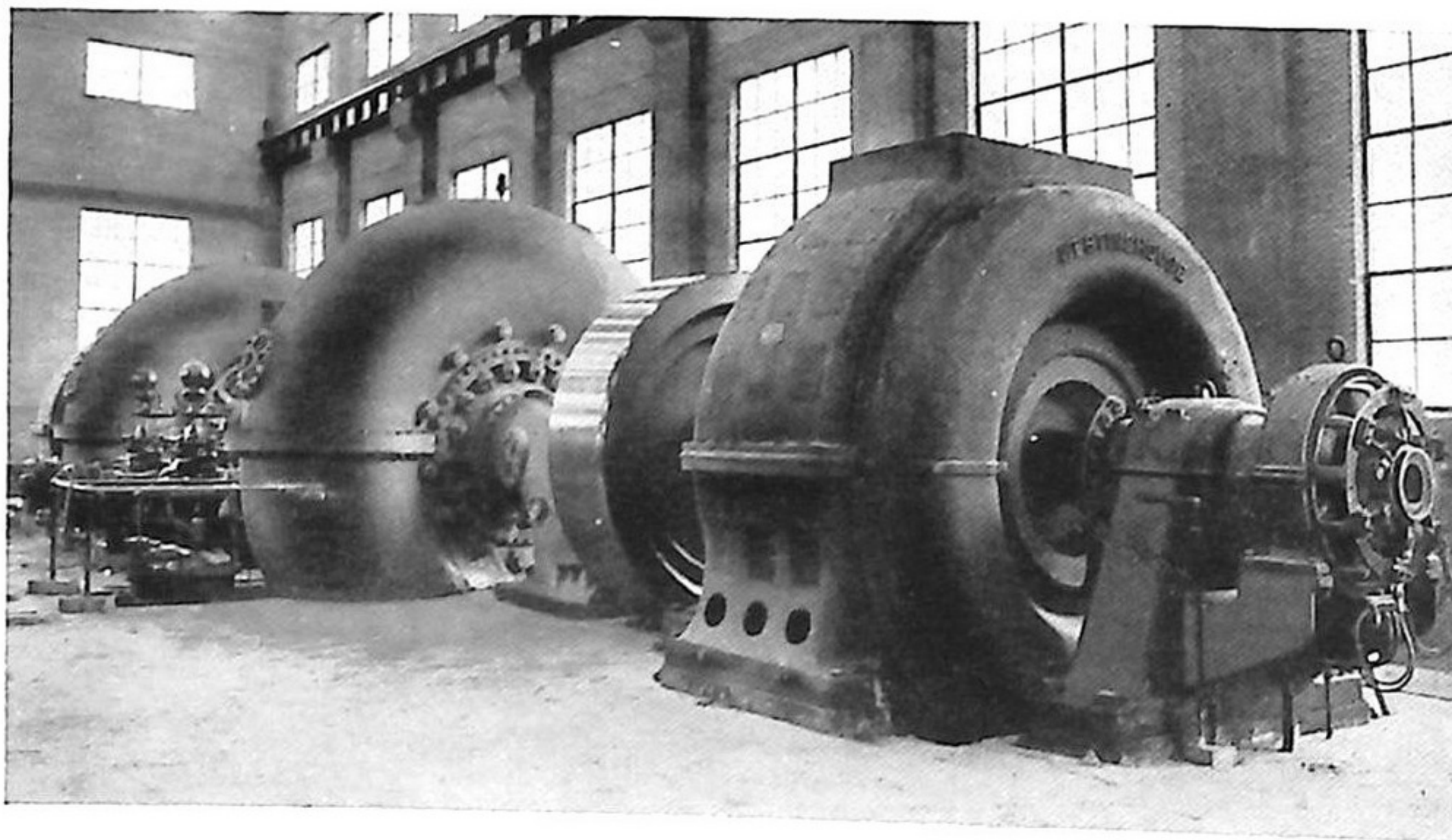
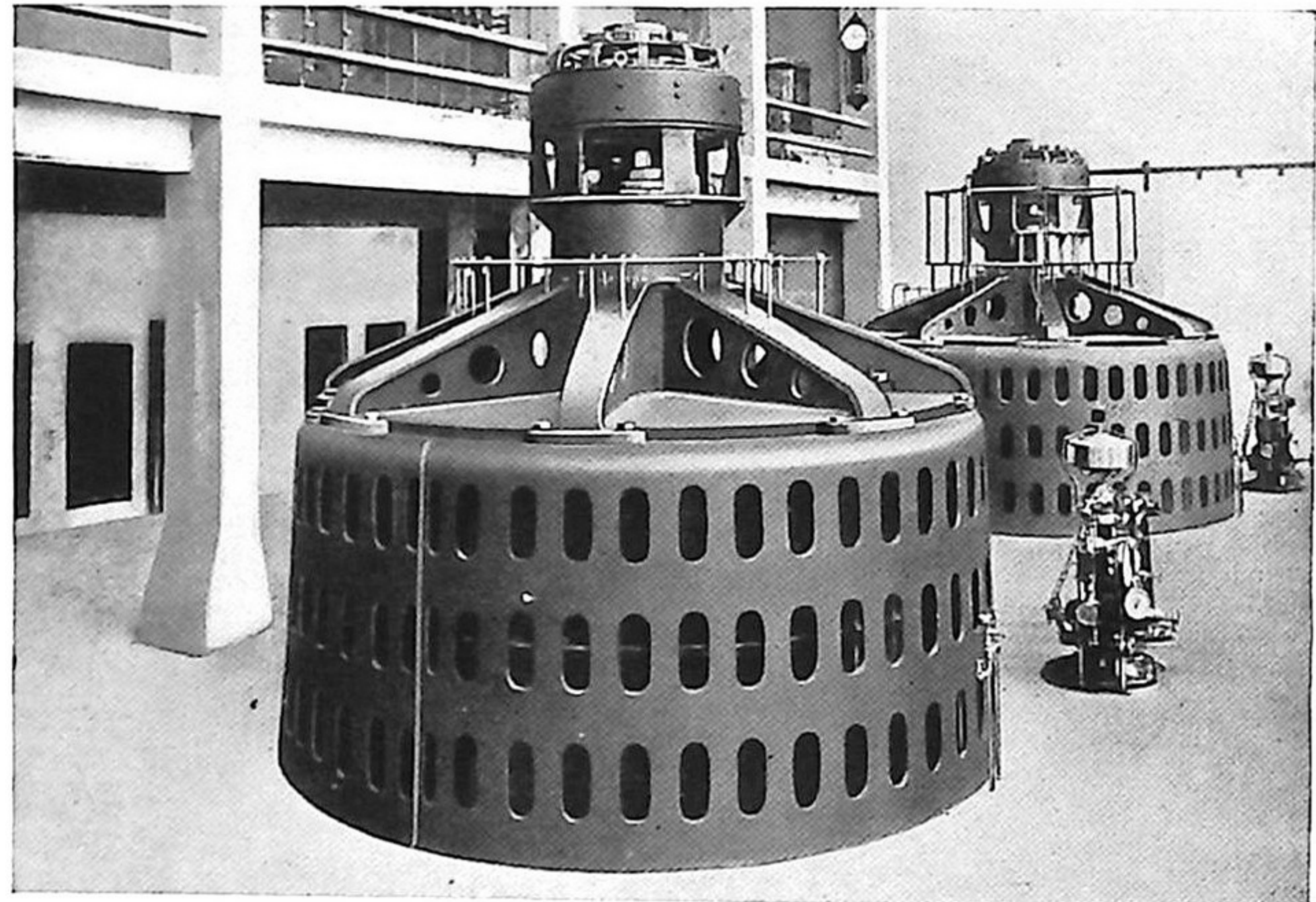
ON ROCK RIVER AT SEARS, ILL. Six 300 kva. units operating under 8 to 13 foot head. Speed, 72 rpm.
Generating voltage, 2,300. Transmission lines, 33,000 volts.

Waterwheel Generators



BIG CREEK NO. 2 PLANT OF SOUTHERN CALIFORNIA EDISON CO., houses two 17,500 kva. Westinghouse Generators. Head is 1,780 feet; and speed, 375 rpm. Generator voltage, 6,600. Transmission line to Los Angeles, 150,000 volts.

ROCHESTER RAILWAY & LIGHT CO., ROCHESTER, N. Y. Two 12,500 kva. Generators, 180 rpm. Head, 130 feet. Generating and transmission voltage, 11,500. Excitation at 250 volts and direct connected to main units.



NIAGARA, LOCKPORT & ONTARIO POWER CO. PLANT, ALTMAN, N. Y., houses four 6,588 kva. Generators, operating under 245 foot head, at a speed of 375 rpm. Generator voltage of 6,600 is stepped up to 66,000 for transmission to Syracuse, N. Y. Excitation supplied by direct-connected exciters.

Construction

Stators

ALL stator frames are rugged iron castings, designed to withstand the stresses incident to manufacture, erection, and operation, as well as provide adequate support for the armature punchings. In addition the frames of vertical machines are usually designed to carry the entire weight of the rotating elements, supported by a bracket bolted to the top of the frame and housing a suitable thrust bearing.

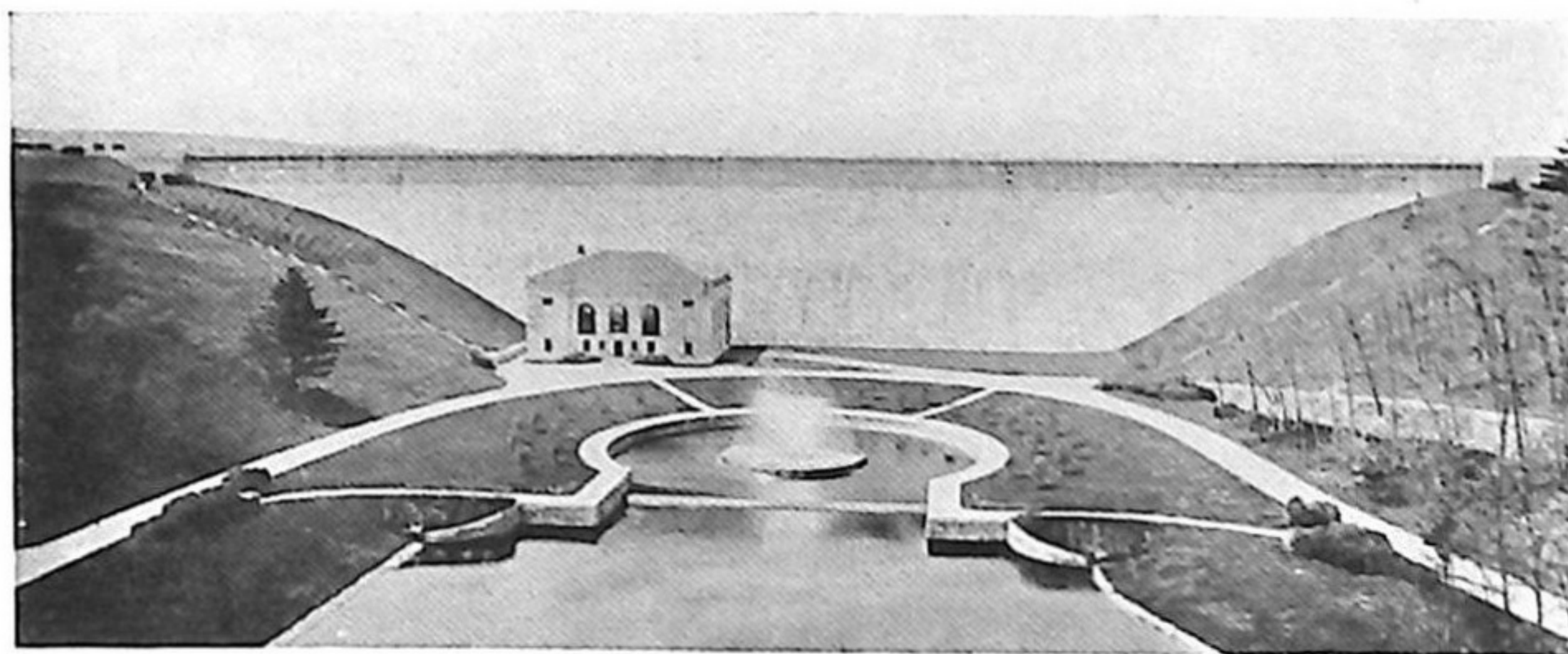
Armature punchings are of thin sheet steel, well japanned after being accurately punched to their finished size. They are carefully assembled, and securely fastened in the frame.

The armature windings are form wound, interchangeable coils, held in the open slots by wedges. Each coil is made up of a number of small rectangular wires, connected in parallel, in series, or in a series-parallel combination. The wires may be insulated with cotton, or with mica. Each coil is impregnated—a heat and vacuum treatment—with a special varnish or gum to eliminate air pockets and fill all spaces between wires.

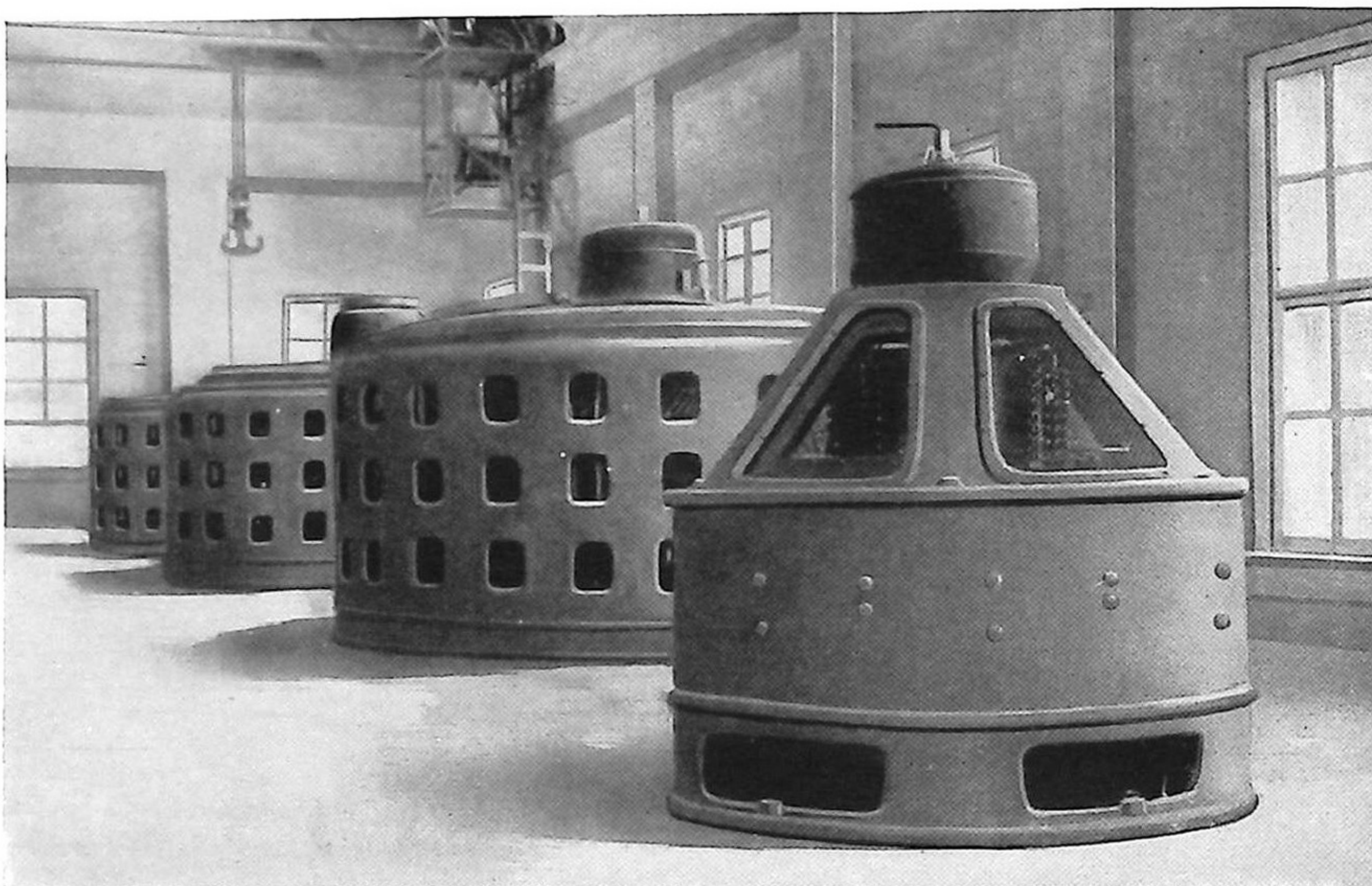
So many generator shut downs are directly traceable to winding troubles that only the best of insulating materials is permissible. Westinghouse generators are invariably insulated between conductors and core with mica, a high heat resistant material, and one impervious to static.

But mica alone does not constitute an element of strength. The method of assembly is as important as the material itself. In this the Westinghouse Company, as the result of twenty-five years of experience, and of constant study devoted to perfecting its application machinery and processes, is a generally recognized leader.

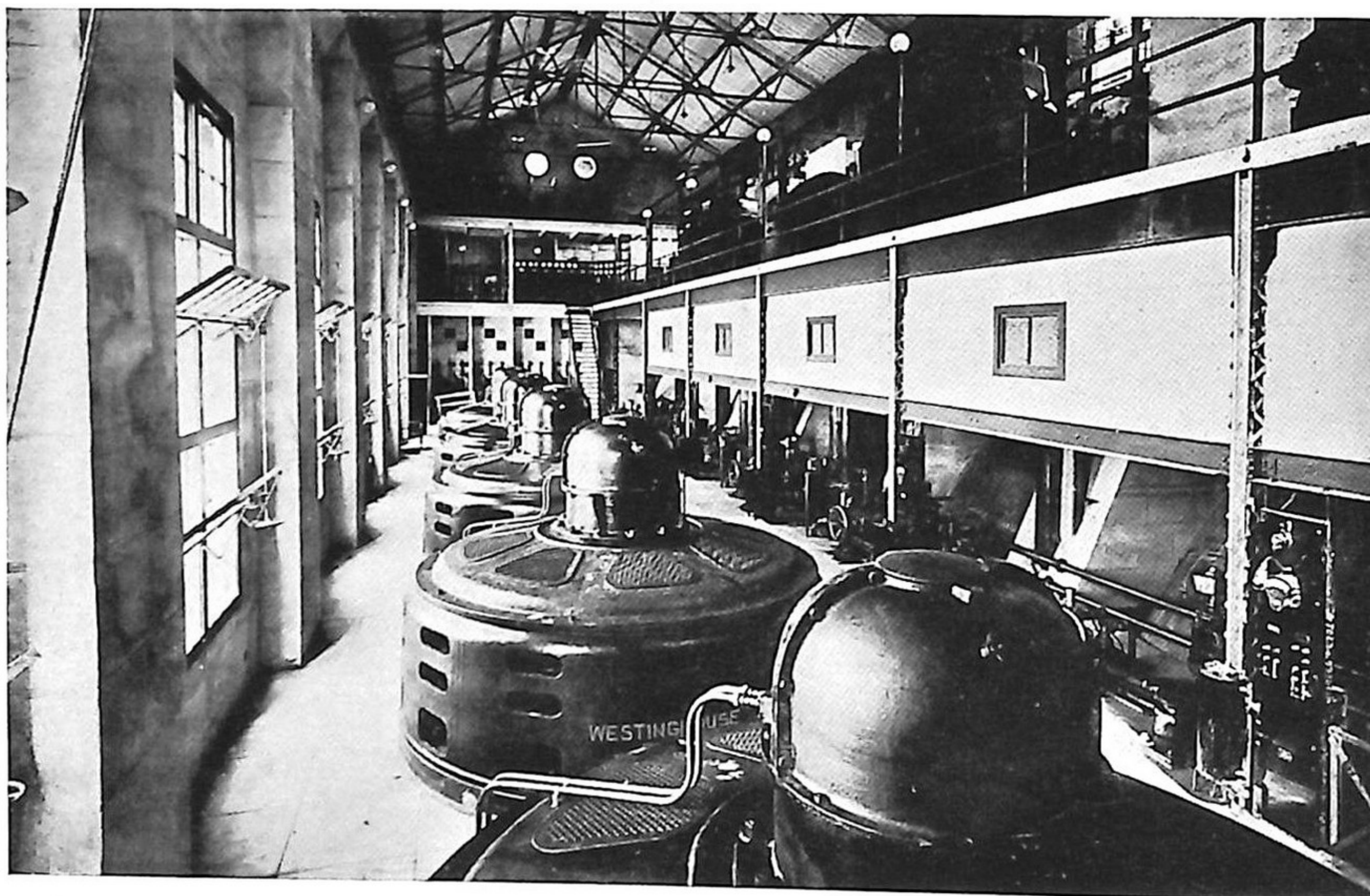
The breaking or grounding of a transmission wire may result in momentary armature currents many times the normal values. At such times the stresses tending to distort the windings are very high. The end turns of the armature windings are accordingly well braced to prevent injury.



Waterwheel Generators

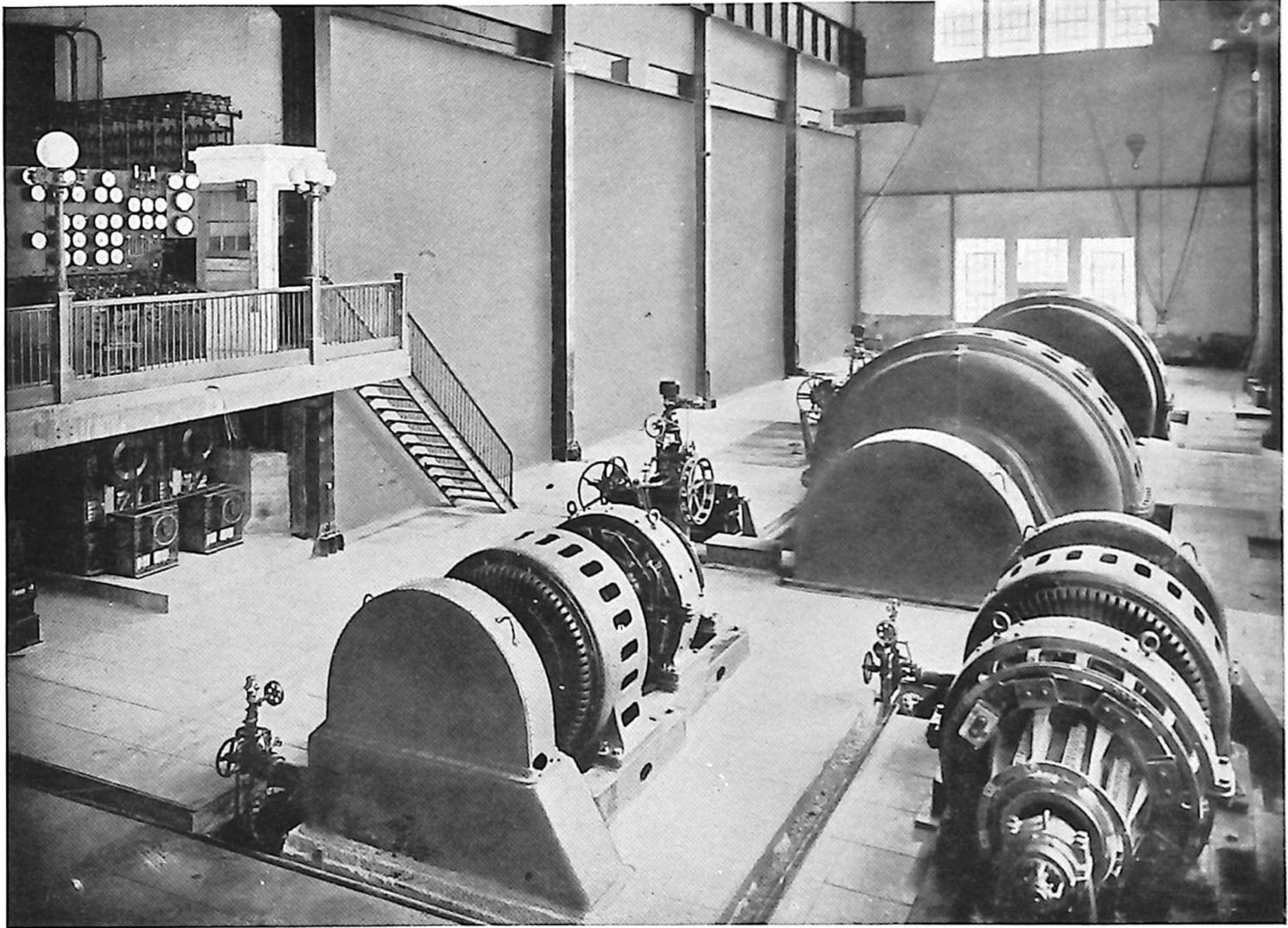


IN SALT RIVER VALLEY, Water Users Association, Phoenix, Ariz., an irrigation project which provides water to drive five 875 Westinghouse Generators. Generating voltage, 11,000. Exciters are separately driven by waterwheel.



MINIDOKA RECLAMATION INSTALLATION, MINIDOKA, IDAHO. Five 1,400 kva. Generators. Speed, 200 rpm. Generating voltage, 2,300. Transmission lines, 33,000 volts. Units operate under 46 foot head. Excitation provided by separate waterwheel-driven exciters.

Waterwheel Generators



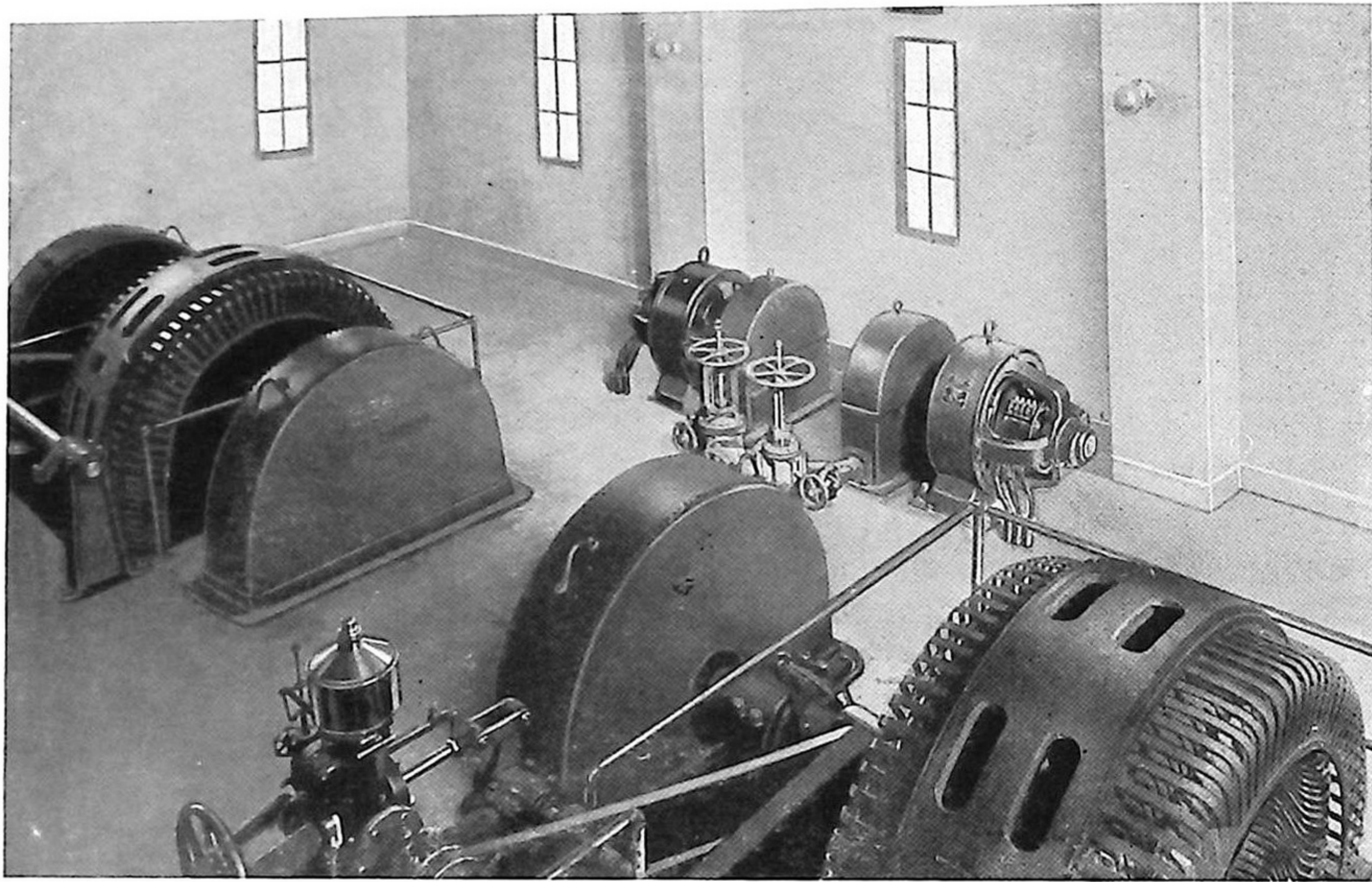
PACIFIC GAS & ELECTRIC CO., CALIFORNIA, has four 12,500 kva., 360 rpm. Westinghouse Generators. Two are in the Drum Plant, head 1,375 feet. Generating voltage, 6,600. Transmission lines, 104,000 volts. Excitation by combined water-wheel and motor drive.

Ventilation

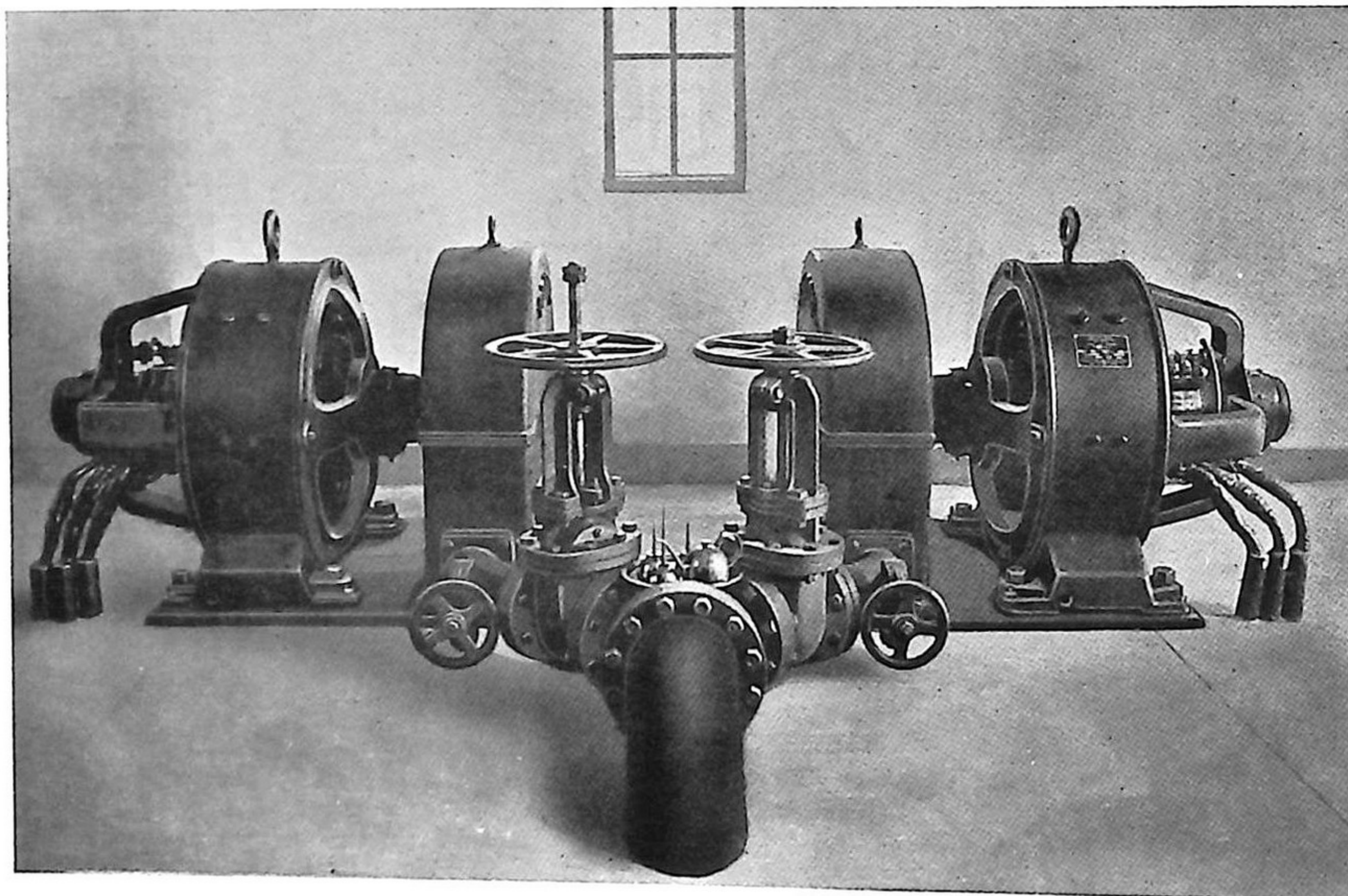
PROPER ventilation is essential to successful operation of waterwheel generators. All rotors are designed, usually by means of ventilating vanes, to draw cooling air into the machine, and air passages or ducts are provided in the stator to distribute it where most effective. By such means "local hot spots" are eliminated and modern and uniform operating temperatures are obtained.

The machine may be open on the sides and take from, and discharge its cooling air, into the generator room. Or enclosing end bells may be substituted for open ones, in order to distribute the air more effectively. And in some cases, totally enclosed units are supplied, air ducts being provided for inlet or for outlet air, or for both. Capacity, speed, and other details of generator, or of the power house layout, dictate how adequate ventilation is best and most economically to be provided.

Waterwheel Generators



MAIN GENERATING UNITS



EXCITERS

FONTANA POWER COMPANY, FONTANA, CALIFORNIA. Two 1,200 kva. Generators operating at 375 rpm. under a head of 542 feet. Generating voltage is 11,000. All power generated is fed into Southern California Edison System.

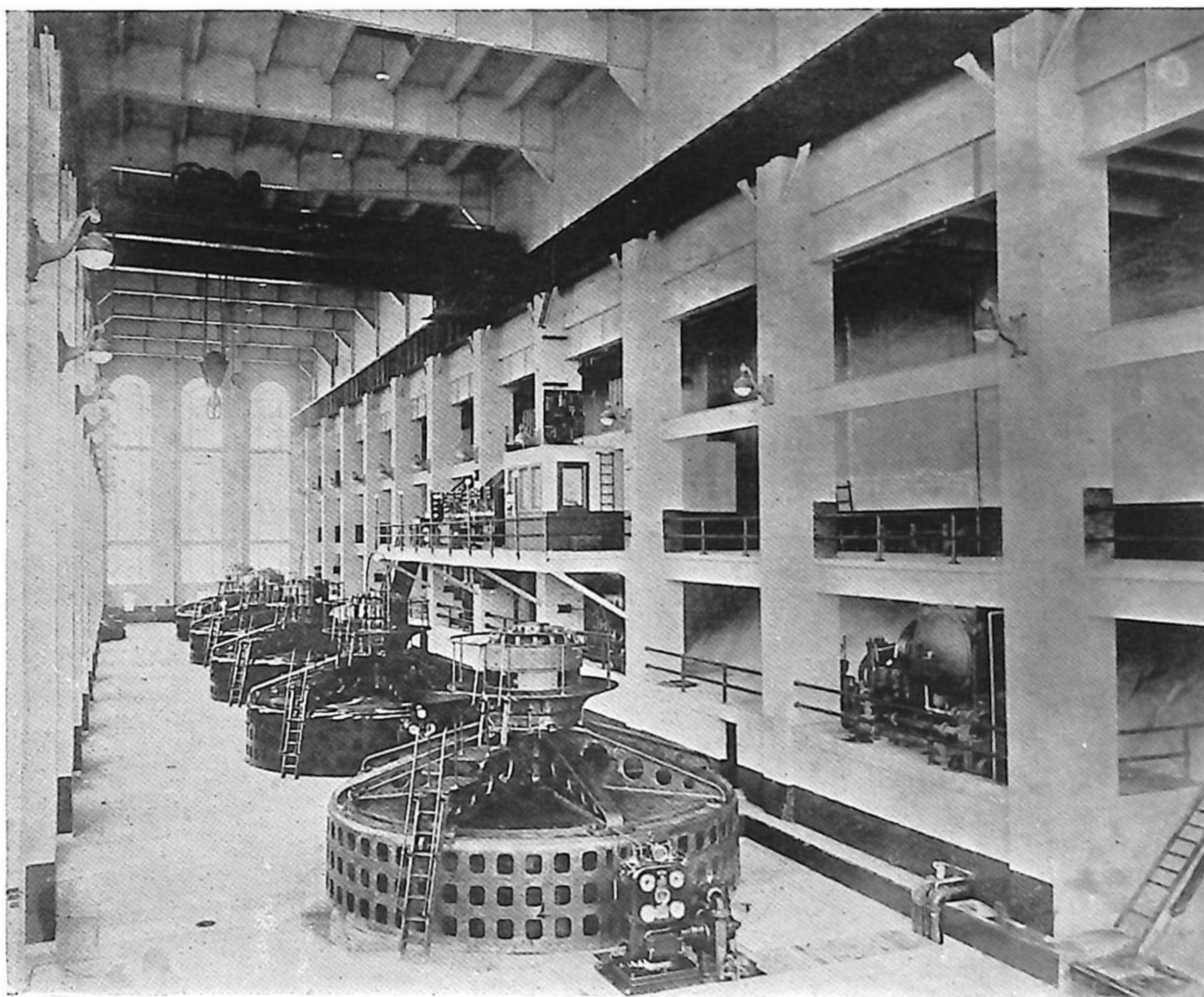
Waterwheel Generators

Rotors

GENERATOR rotors are sufficiently strong to withstand the runaway speed of the connected waterwheel. This may vary from 50 to 80 per cent above normal.

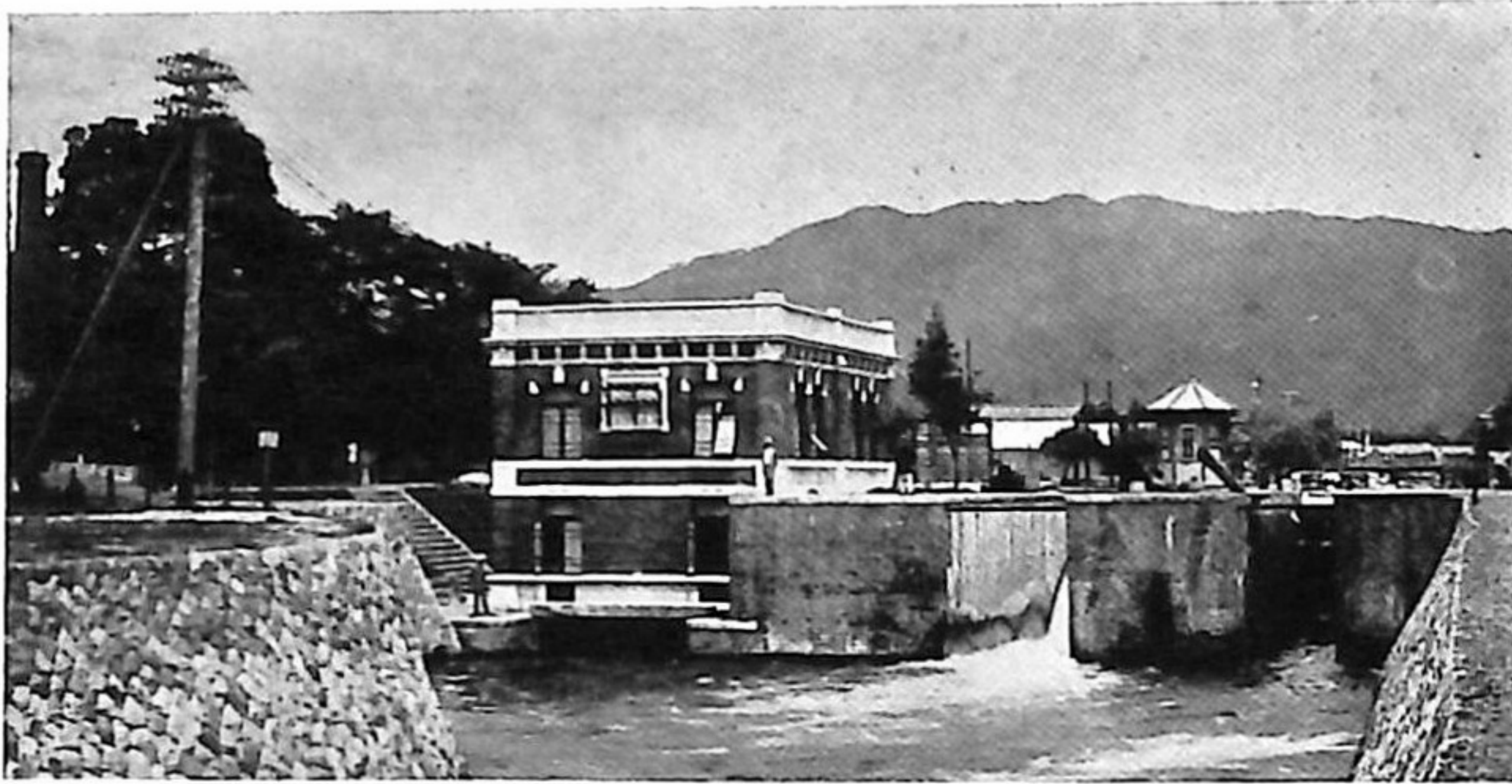
The wide differences in speeds and capacities of waterwheel machines, make the rotor design, when complicated by overspeed requirements, a difficult one. A safe construction may not be economical, and an economical one not safe.

Iron castings may be used for low peripheral speeds. For higher stresses cast steel is employed. Rolled steel plates offer a very uniform and a very strong material for high speed units, but plates of large diameter are not made. Where sufficiently large plates are unavailable, and large steel castings are likely to have hidden defects, the Westinghouse laminated rim construction solves the problem. Here again our wide experience promises a safe and a wise choice.

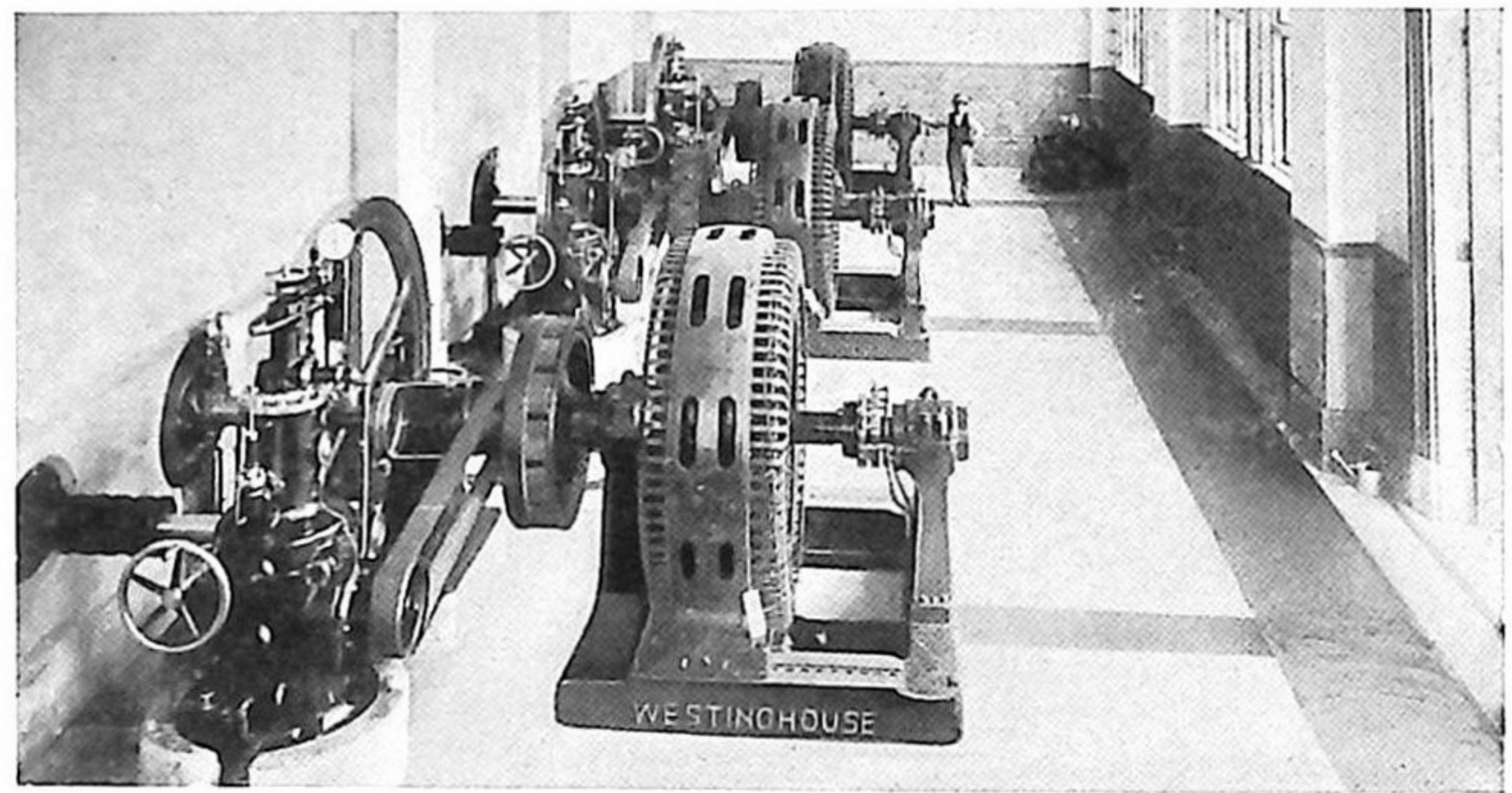


ALABAMA POWER CO'S. PLANT AT LOCK NO. 12 ON COOSA RIVER, ALABAMA. Largest "hydro" plant in that State. Houses five 13,500 kva. Westinghouse Generators operating under head of 68 feet, and running at a speed of 100 rpm. Units supply a large mining, manufacturing and general power load. Generating voltage, 6,600 and transmission to Birmingham and surrounding territory, 110,000 volts. Excitation by direct-connected exciters, wound for 250 volts.

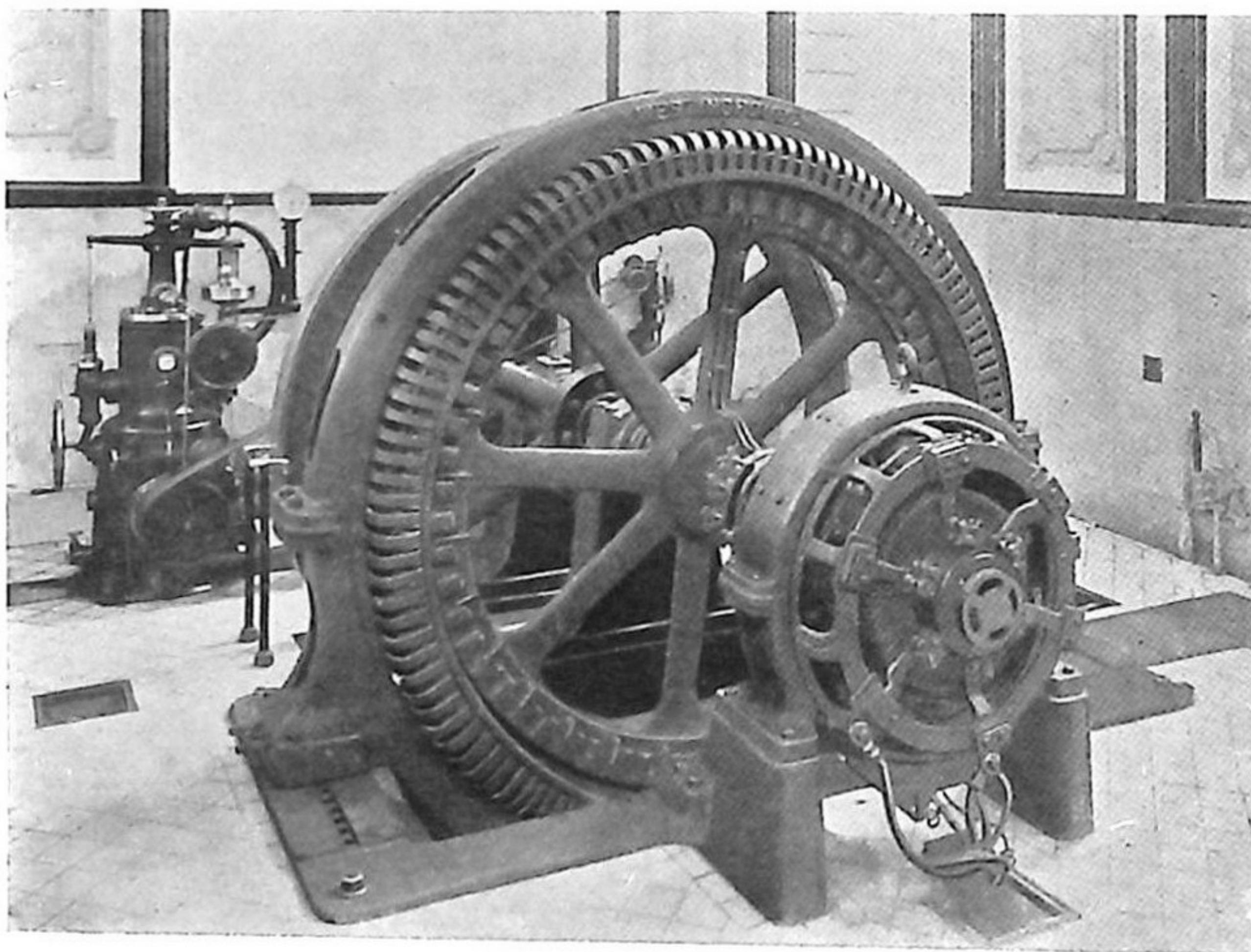
Waterwheel Generators



EXTERIOR



INTERIOR



WESTINGHOUSE GENERATORS built at the Company's main Works, East Pittsburgh, Pa., are shipped to all parts of the Globe. Views show installations of three 250 kva., and one 350 kva. Generators in Japan.

Waterwheel Generators



ELECTRO METALLURGICAL COMPANY, GLEN FERRIS, WEST VA. Six 350 kva. vertical Generators operating under a head of 25 feet and at a speed of 120 rpm. Generators are wound for 110-volt service and furnish power for electric furnaces in the making of ferro alloys. Excitation is provided by separate waterwheel excitors.

Mechanical Parts

WATERWHEEL generators are usually self-contained units, connected to the waterwheel through couplings. A rigid shaft, and strong, rugged bearings and bases, are necessary to prevent mechanical troubles—therefore Westinghouse designs retain a large “factor of safety.”

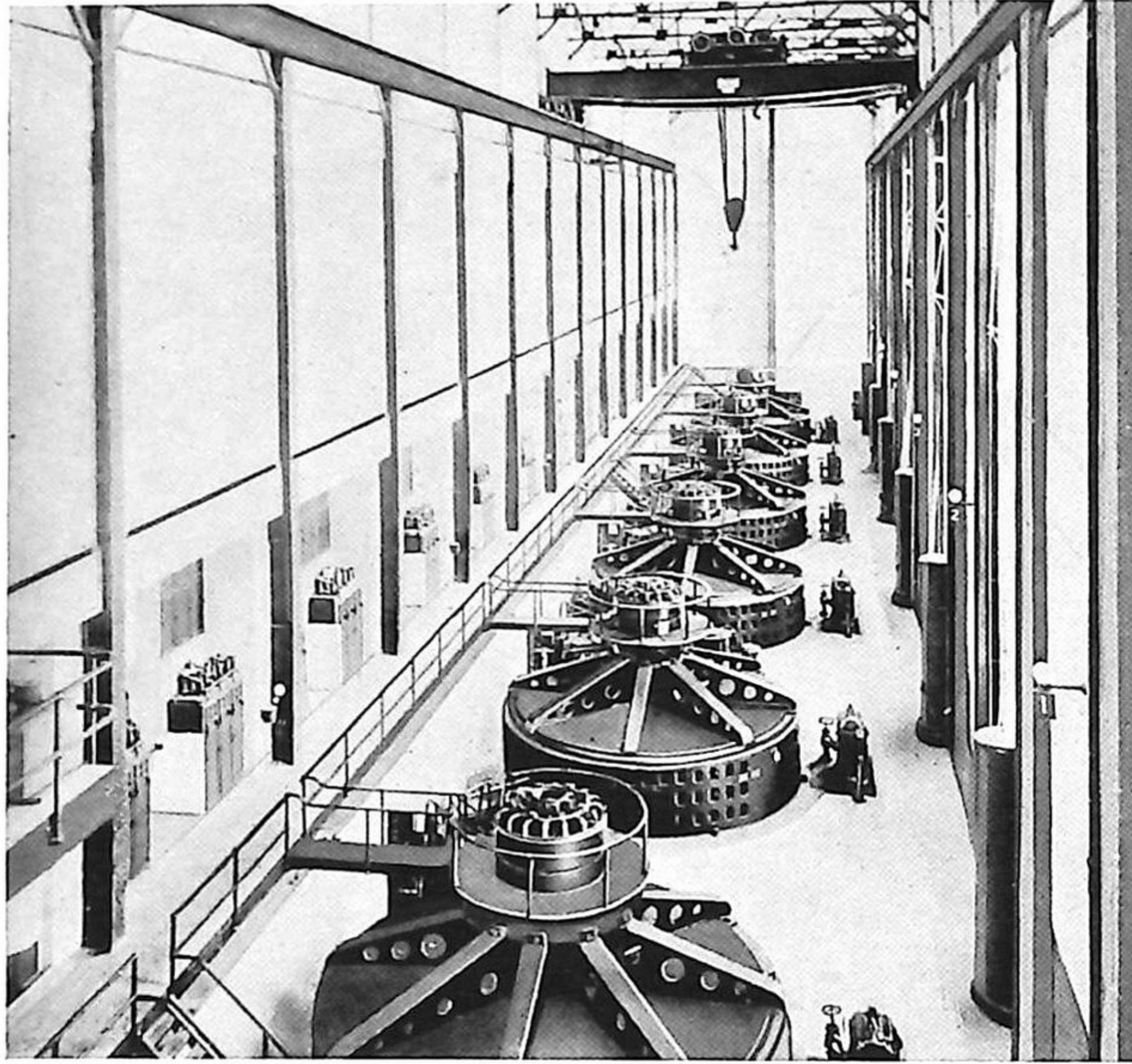
Horizontal Units

FOR horizontal service the machine has two babbitt lined, self-lubricating bearings, a single bedplate to support the stator feet and the bearings, and a shaft arranged for extension for coupling.

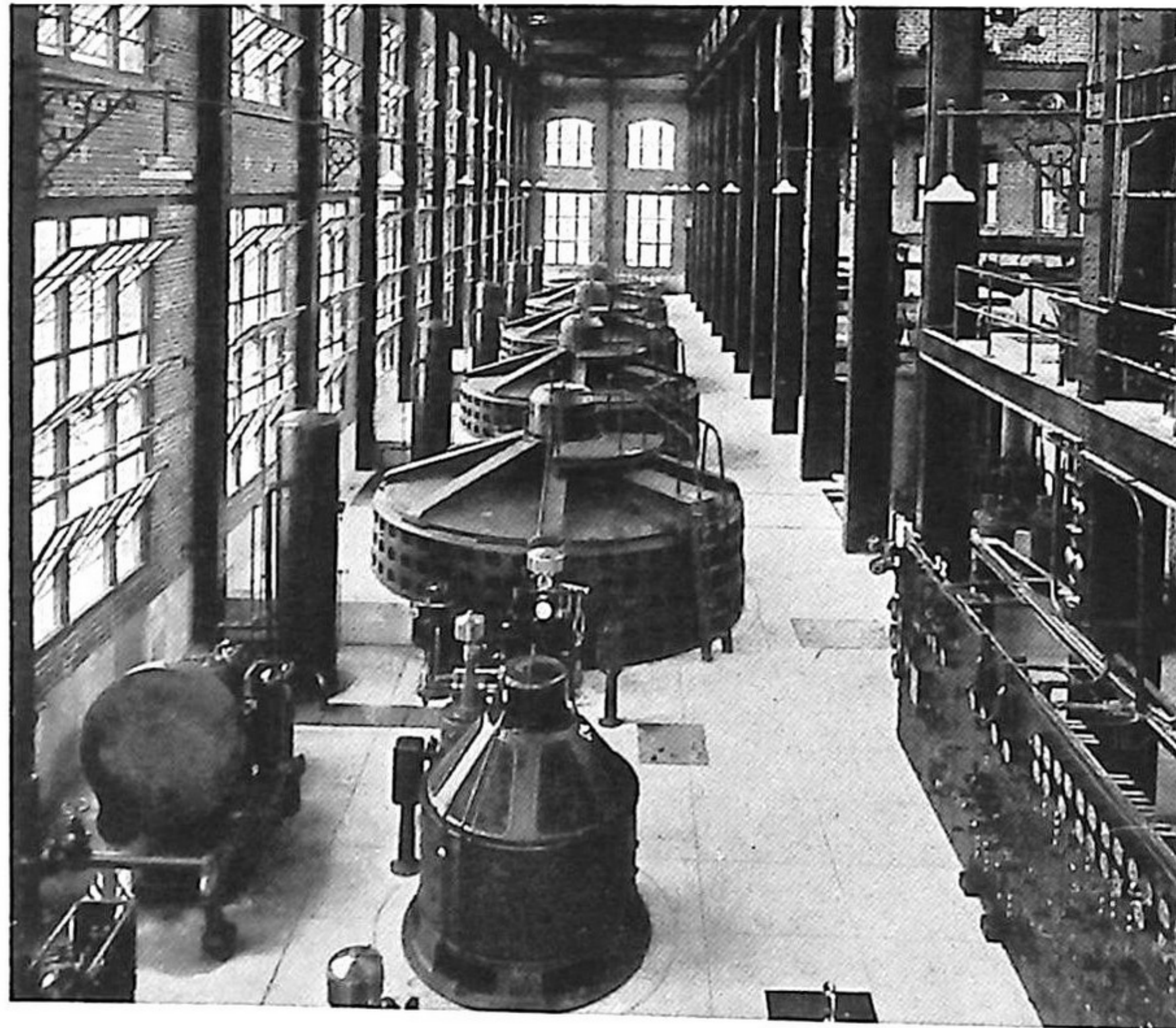
Separate pads for each stator foot, and each bearing pedestal, may be, and often are, substituted for the single bedplate type of support.

Pelton impulse wheels are frequently mounted directly on generator shaft extension, sometimes one on each side of the machine. Extra strength is added in shaft and in bearings whenever overhung waterwheels are contemplated.

Waterwheel Generators



LAURENTIDE POWER CO., PROVINCE OF QUEBEC, CANADA. Six 14,700 kva., 120 rpm. Generators with direct-connected exciters. Head is 85 feet. Power load for electro-chemical industries, paper and pulp manufacture, etc. Generating voltage, 6,600.



AUGUSTA, GA. Five 2,700 kva., 75 rpm. Generators supplying cotton mill, railway and power load. Head is 100 feet. Generating voltage, 2,300. Trans-driven exciters.

Waterwheel Generators



HOLTER PLANT OF MONTANA POWER CO. Four 12,000 kva., 150 rpm., Westinghouse Generators furnish power for mining, metallurgical and railroad electrification load. Hydraulic head, 109 feet. Generating voltage, 6,600, transmission lines, 107,000 volts. Excitation for generators supplied by separate waterwheel-driven excitors.

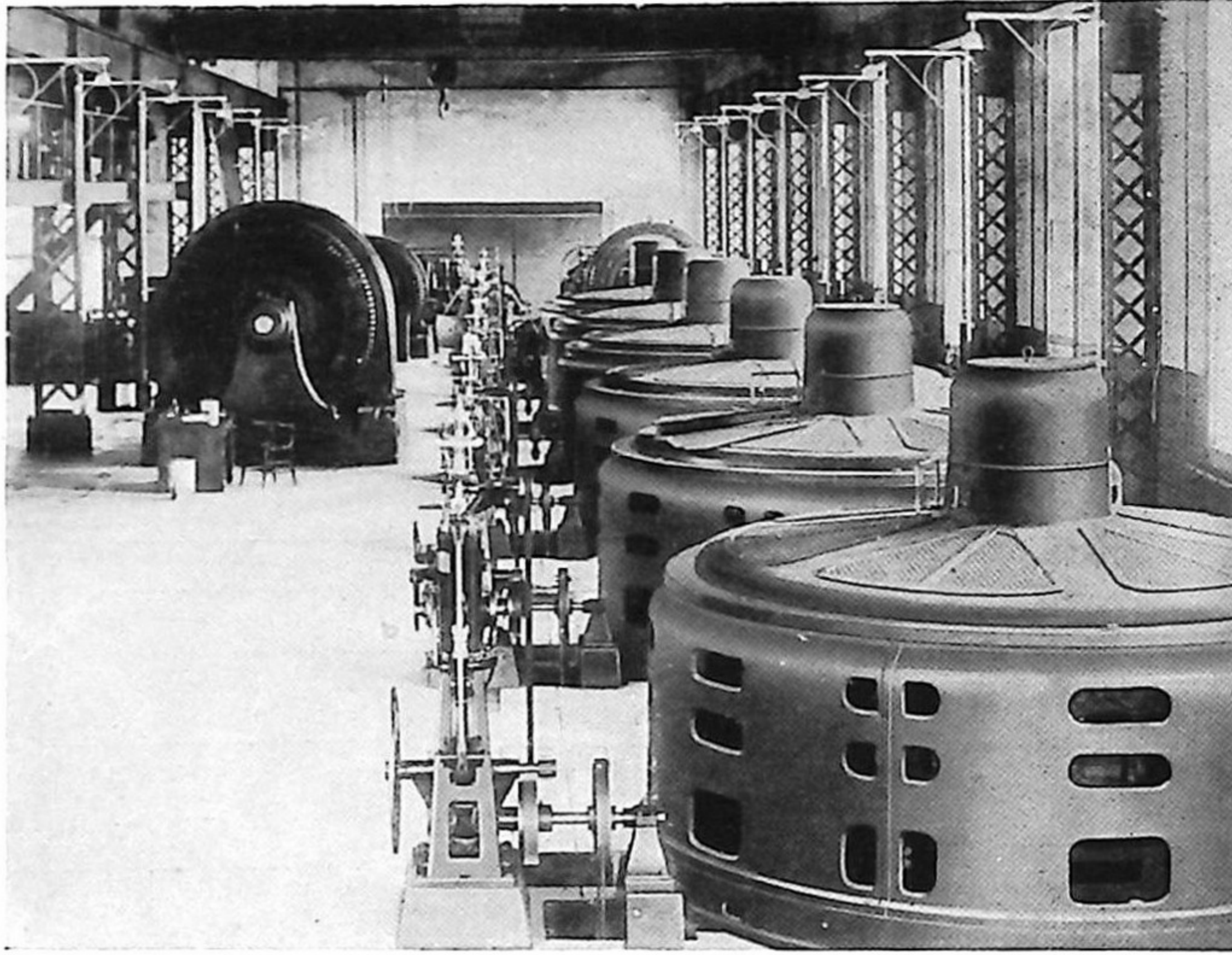
Vertical Units

THE vertical unit may be considered as a horizontal one set on end. The two supporting bearings in the horizontal machine become the two guide bearings centering the rotor of the vertical type. To carry the weight of generator and waterwheel rotors, and the unbalanced water thrust, a Kingsbury bearing is added and mounted above the upper guide bearing.

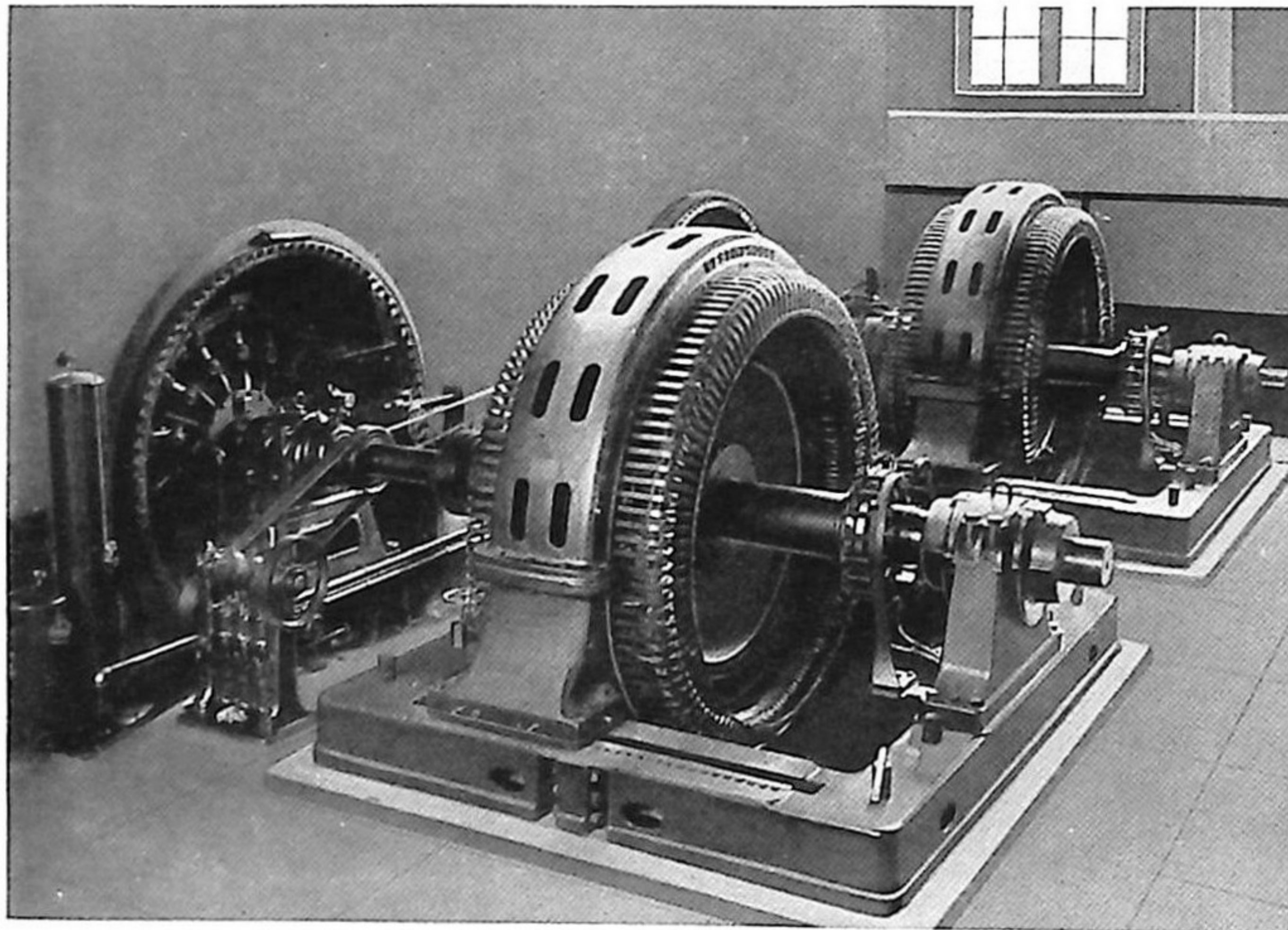
The guide bearings are carried in brackets bolted to top and bottom of stator frame. The Westinghouse I-beam type of bracket combines minimum weight with maximum strength and rigidity. It has several arms spaced radially from center and bolted to frame at equidistant points.

Where distance between generator and waterwheel is small the lower guide bearing is sometimes omitted, one generator and one waterwheel bearing centering the complete revolving element.

Waterwheel Generators

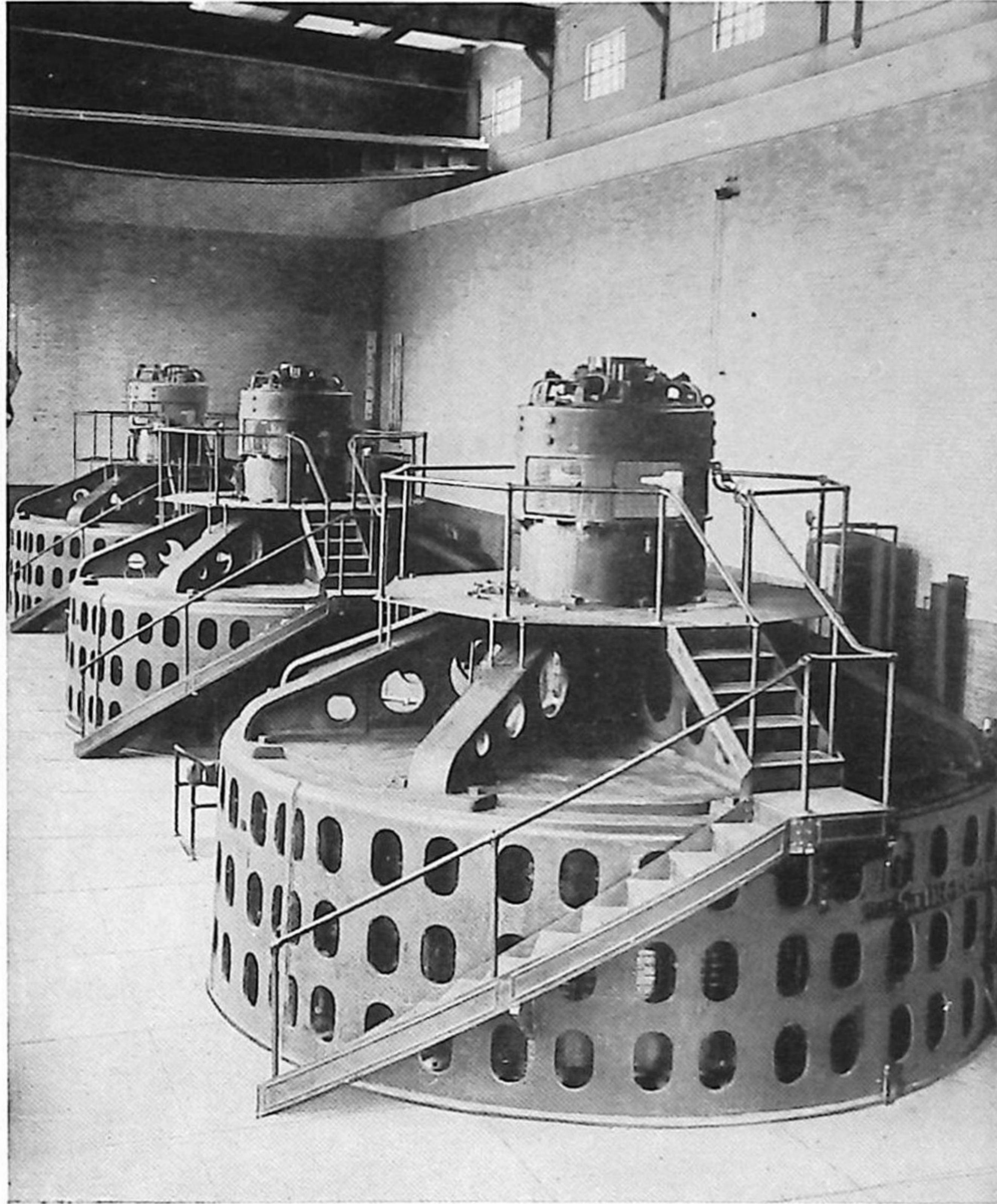


MARSEILLES PLANT ON ILLINOIS RIVER. Six 320 kva. Generators. Head, 11 feet. Speed, 75 rpm. Serves traction and power load. From a 2,300 volt bus, the voltage is stepped up to 33,000. Excitation by separate waterwheel units and motor generator set.



COLUMBUS POWER COMPANY, COLUMBUS, GA. Two 3,750 kva. Generators. Speed, 225 rpm. Generating and transmission voltage, 12,000. Separate waterwheel exciters.

Waterwheel Generators



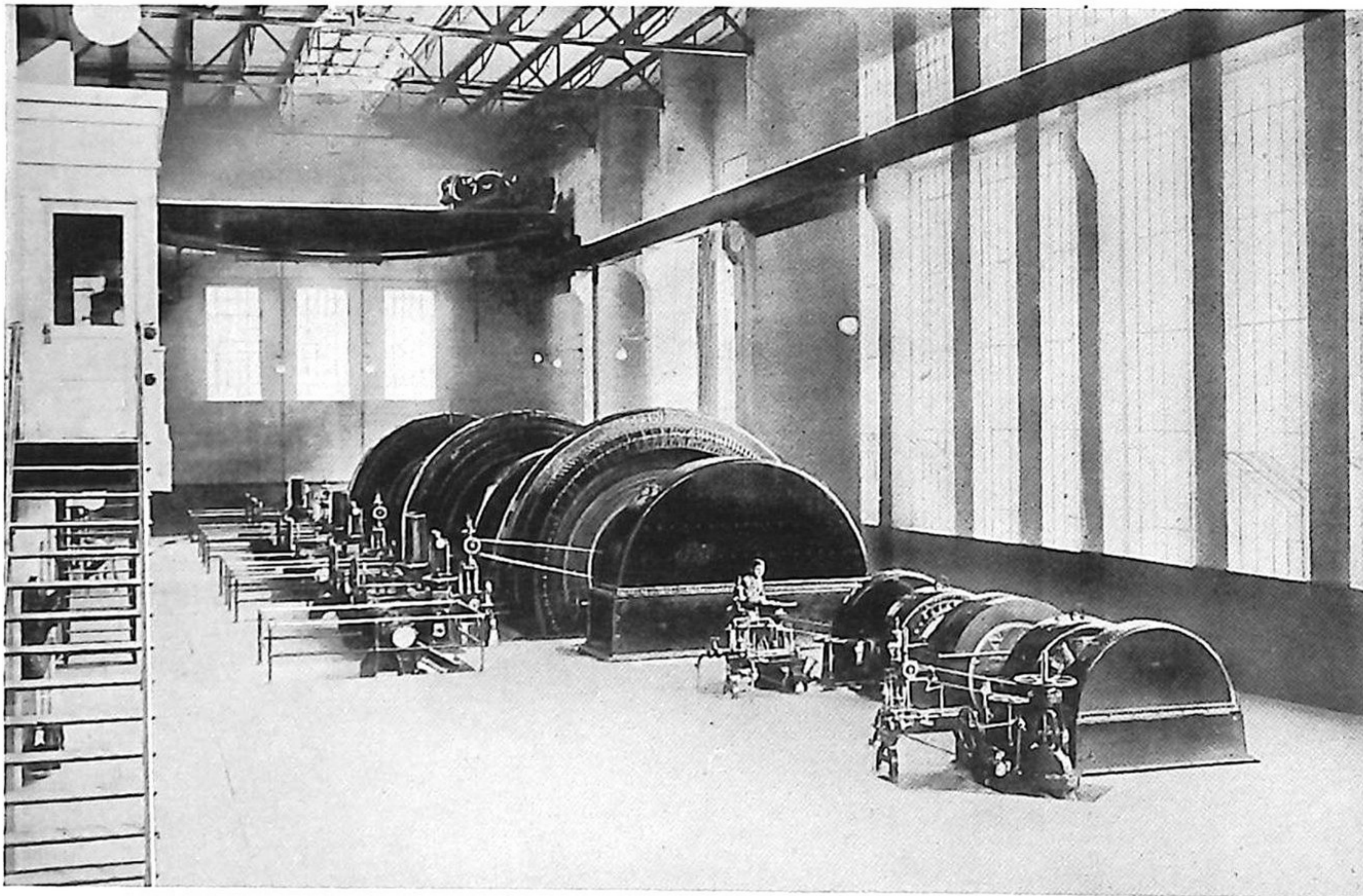
LARGEST "HYDRO" STATION IN LOWER PENINSULA OF MICHIGAN, the "Junction Plant" of the Consumers Power Co. Three 6,250 kva. Westinghouse Generators, operating under head of 51 feet and speed of 100 rpm. Units have 250 volt direct-connected exciters. Generating voltage 6,600, transmission voltage, 140,000.

Vertical Units—Continued

A circular bedplate pad grouted into foundations, and to which stator can be bolted and dowelled after all alignments are made, is generally provided.

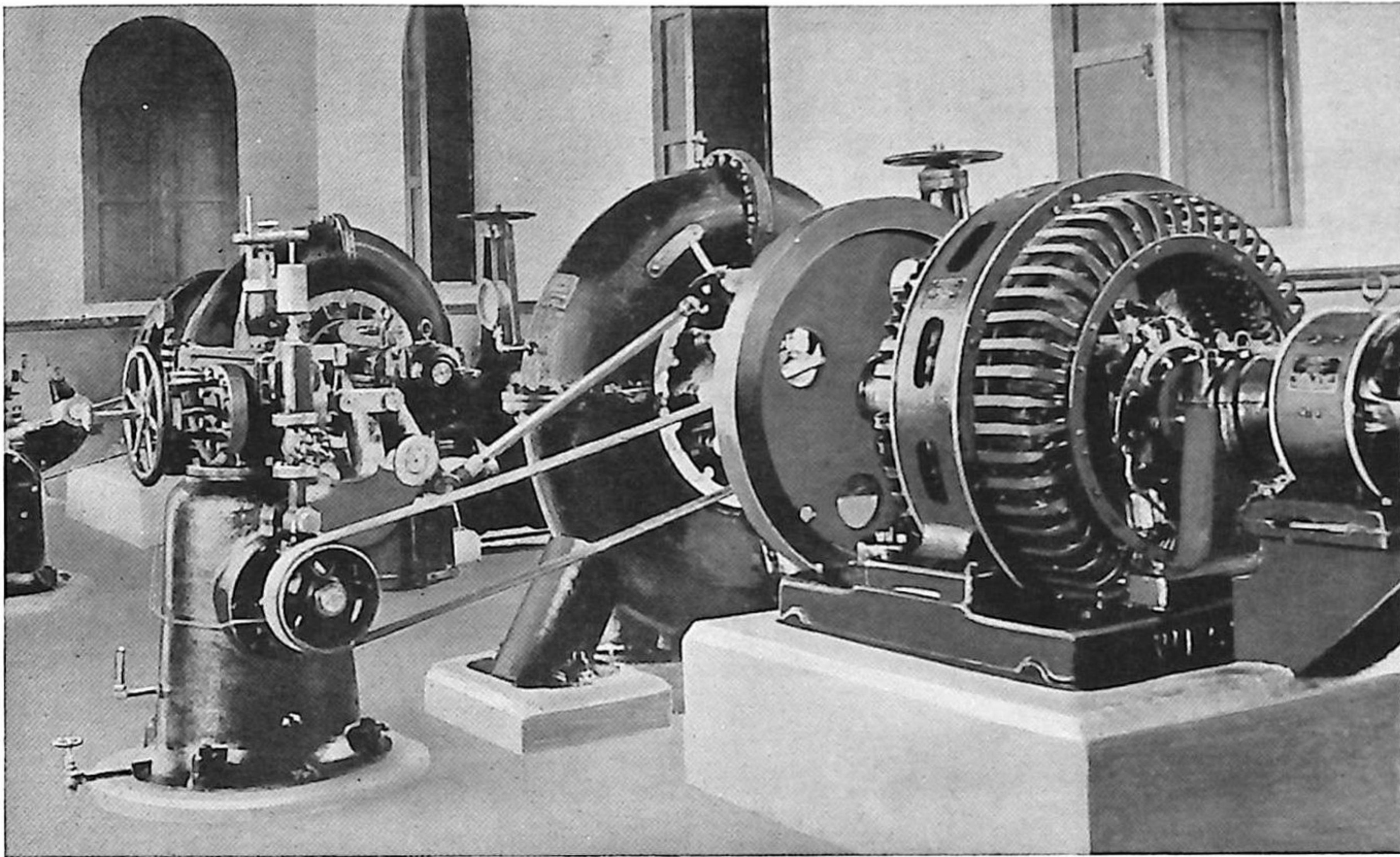
Some means for circulating the lubricating oil is necessary with vertical units. With small and medium capacity machines this may be a pump geared to main shaft, and forcing the oil up to the thrust bearing housing, from whence it flows by gravity to guide bearings and back to pump. For large machines, or for stations containing a number of vertical units, a separate system, consisting of motor driven pump, tank, filter, and piping is ordinarily installed.

Waterwheel Generators



UTILIZING THE POWER AVAILABLE FROM A LARGE CITY'S WATER SUPPLY. Three 9,375 kva. Generators operating under a head of 938.2 feet. San Francisco Plant, Los Angeles, Cal. Generator speed is 200, voltage 6,600. Power is transmitted to Los Angeles at 100,000 volts. Separate waterwheel drive is used for exciters.

Waterwheel Generators



TWO 100 KVA. WESTINGHOUSE GENERATORS INSTALLED IN COLOMBIA, SOUTH AMERICA. They have direct-connected exciters.

Excitation

THE excitation for waterwheel generators may be provided for in several ways, all perhaps equally serviceable, but differing widely in first cost and in cost of operation. The characteristics of the generators, the power plant layout and the character of its load, largely determine the best system to select.

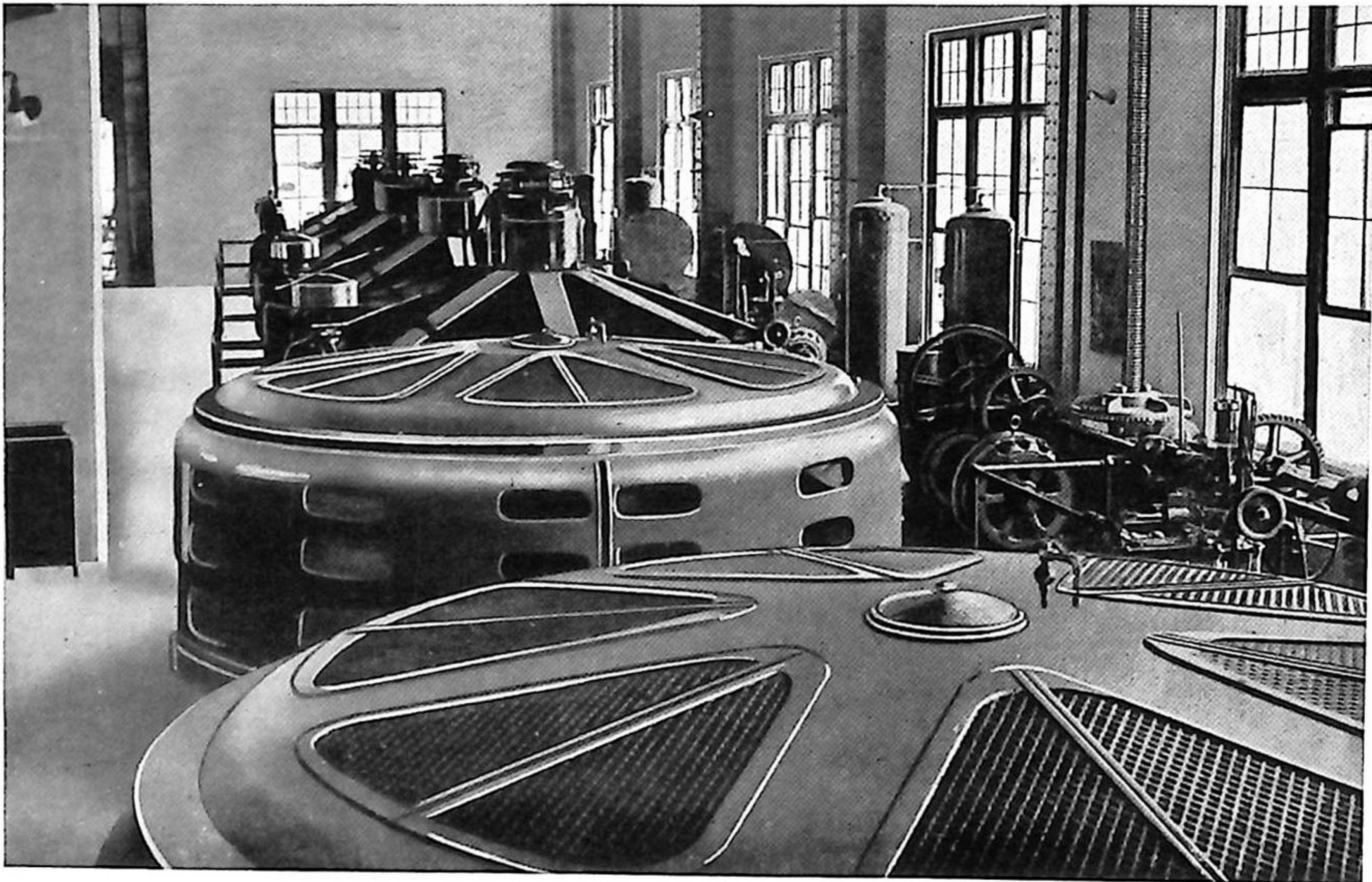
Direct-connected exciters may be a simple and a very satisfactory system for both horizontal and vertical types of units. But for slow speed generators whose percentage of excitation is necessarily high, direct-connected types are both large and expensive.

Separate waterwheel driven exciters, often supplemented by induction motor exciter sets for normal operation, are much employed. A combination waterwheel and motor drive, so arranged that the waterwheel automatically takes the load in case of failure of motor, makes a very satisfactory system in many cases.

For the smaller capacity generators, both horizontal and vertical, standard high speed belted exciters are generally used, this arrangement being the lowest in first cost and fairly acceptable.

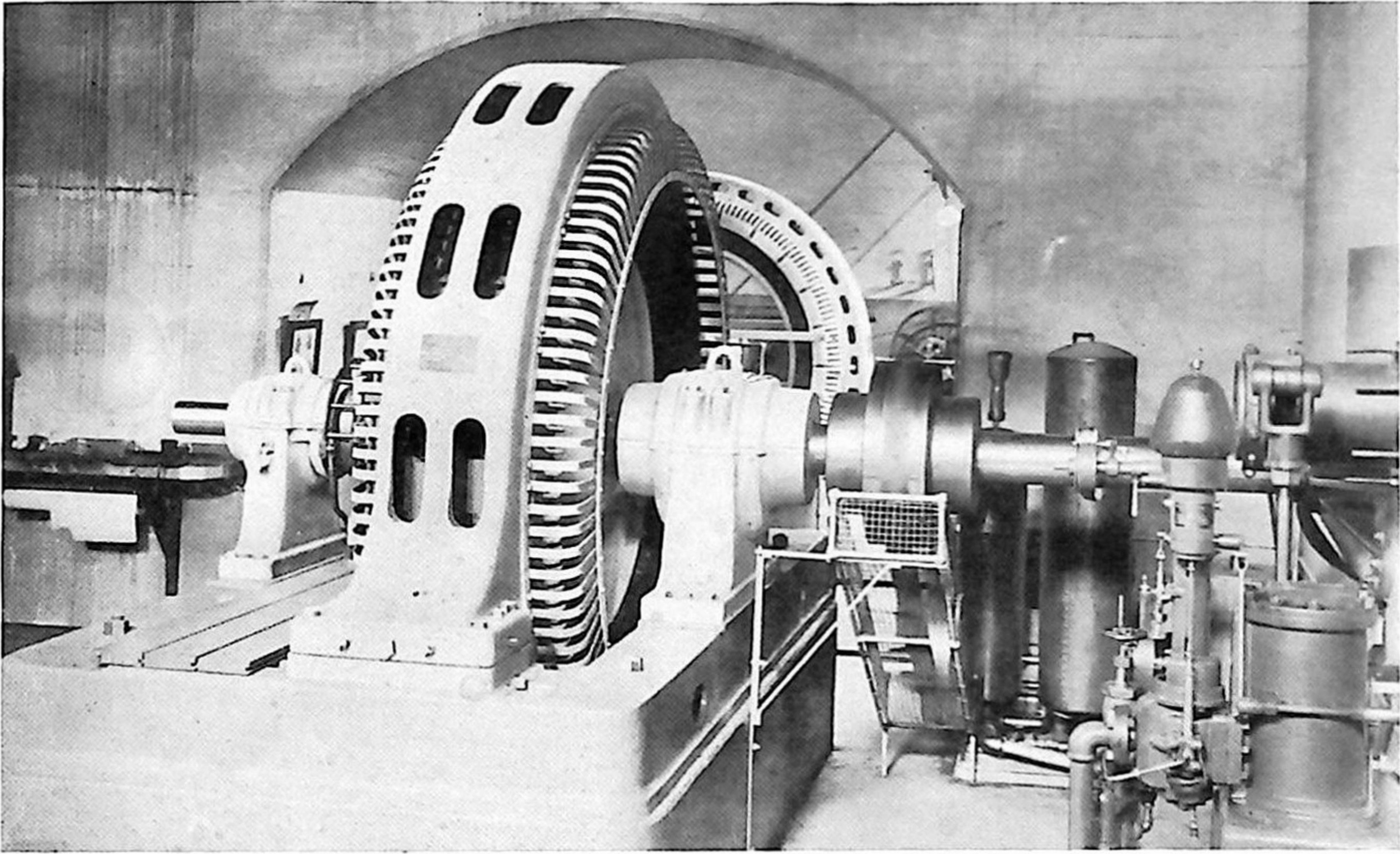
The Westinghouse Company has provided successful apparatus for all the various systems used, and is in a position, through its experience, to offer exciters of maximum efficiency and reliability of that type best suited to the individual case.

Waterwheel Generators

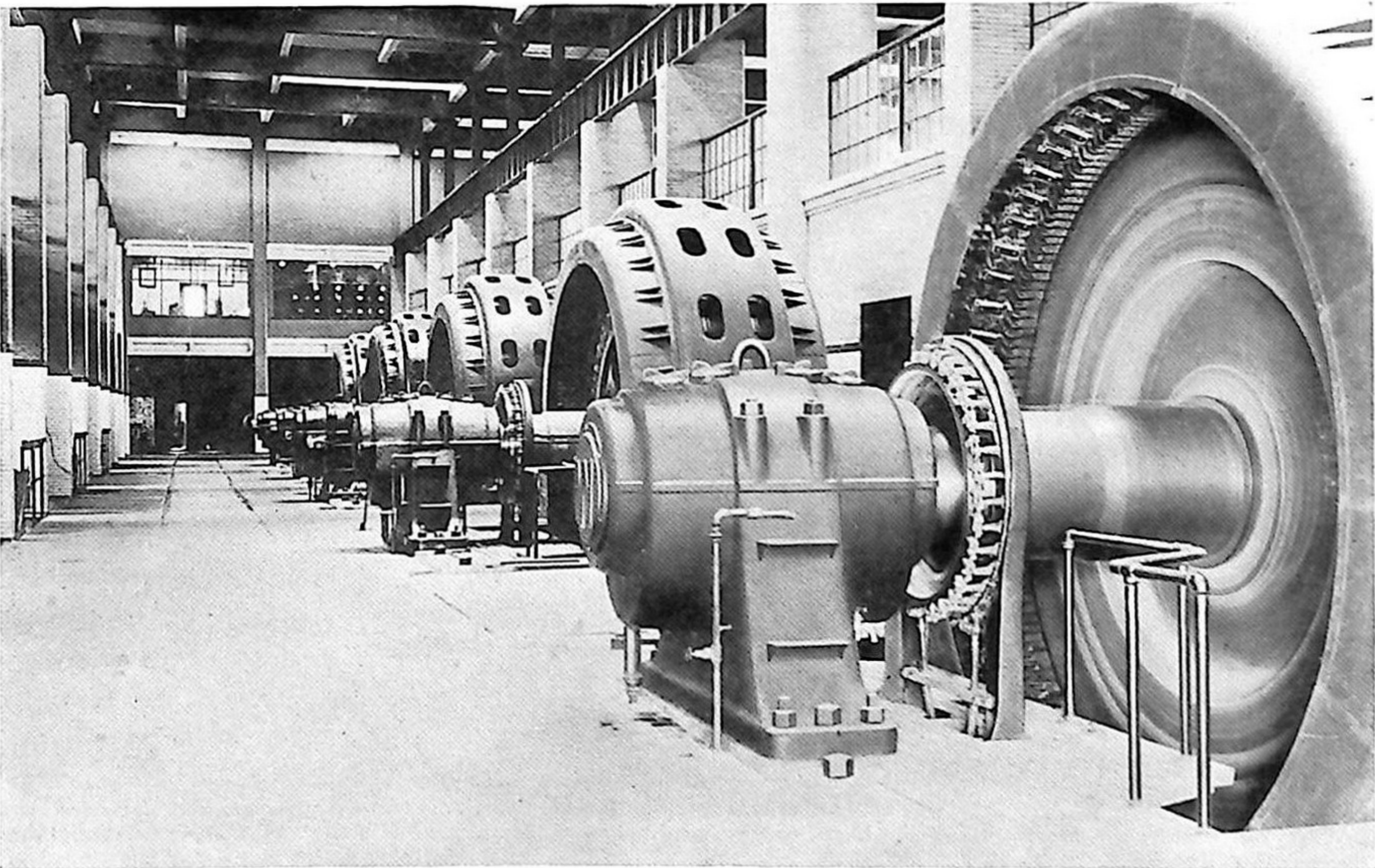


IDAHO POWER COMPANY'S PLANT AT SWAN FALLS, IDAHO, houses two 850 kva. and four 1,560 kva. Generators operating under a head of 17 to 21 feet. The 850 kva. units operate at 120 rpm., the 1,560 kva. units at 90 rpm. All current is generated at 2,300 volts, and is stepped up to three high tension voltages, connecting with three subdivisions of the transmission system, one of 22,000 volts, one of 44,000 volts and one of 66,000 volts.

Waterwheel Generators

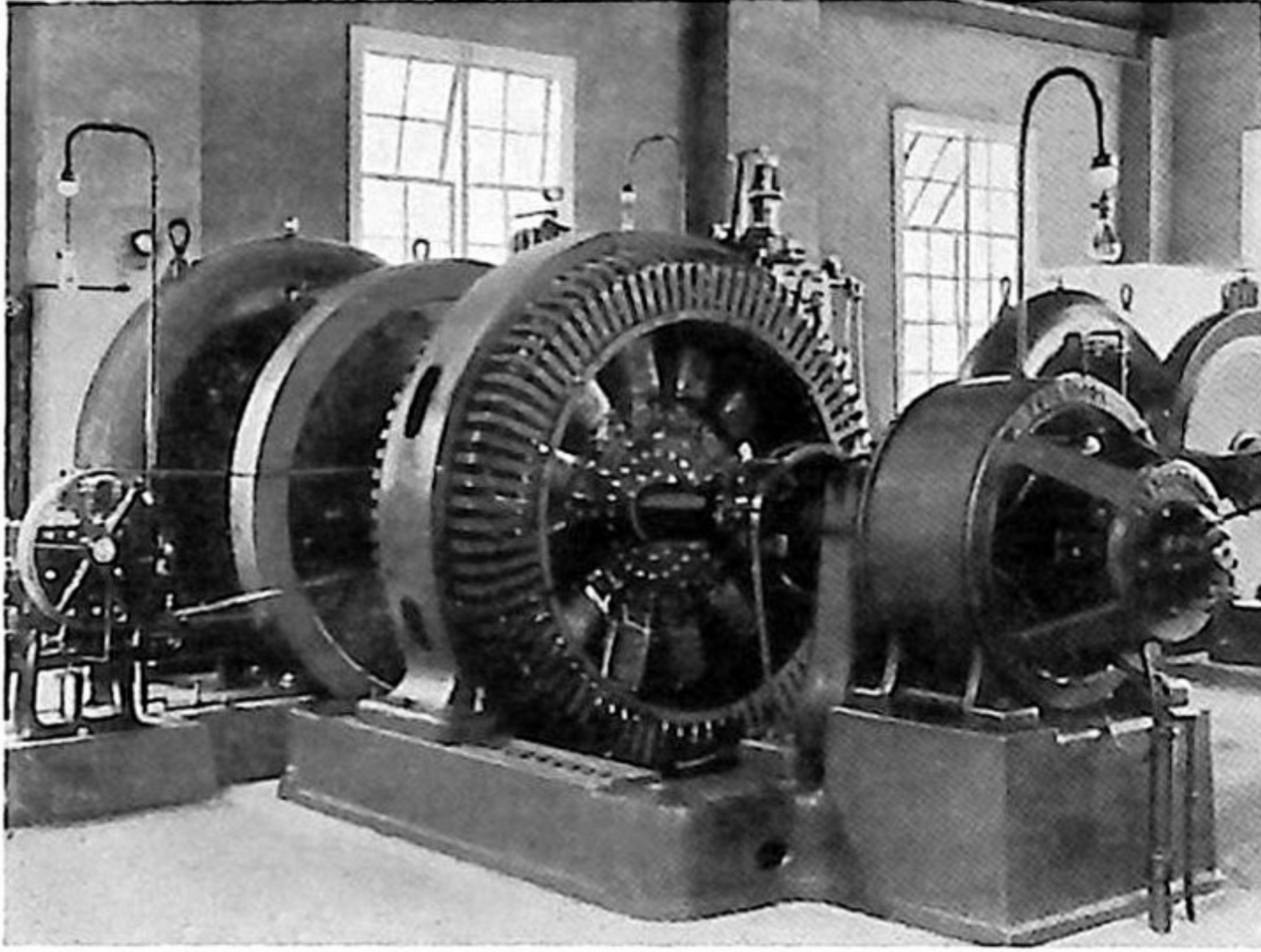


CROWN WILLAMETTE PAPER COMPANY, CAMAS, WASH. One 1,250 kva. Westinghouse Generator operating at 240 rpm.

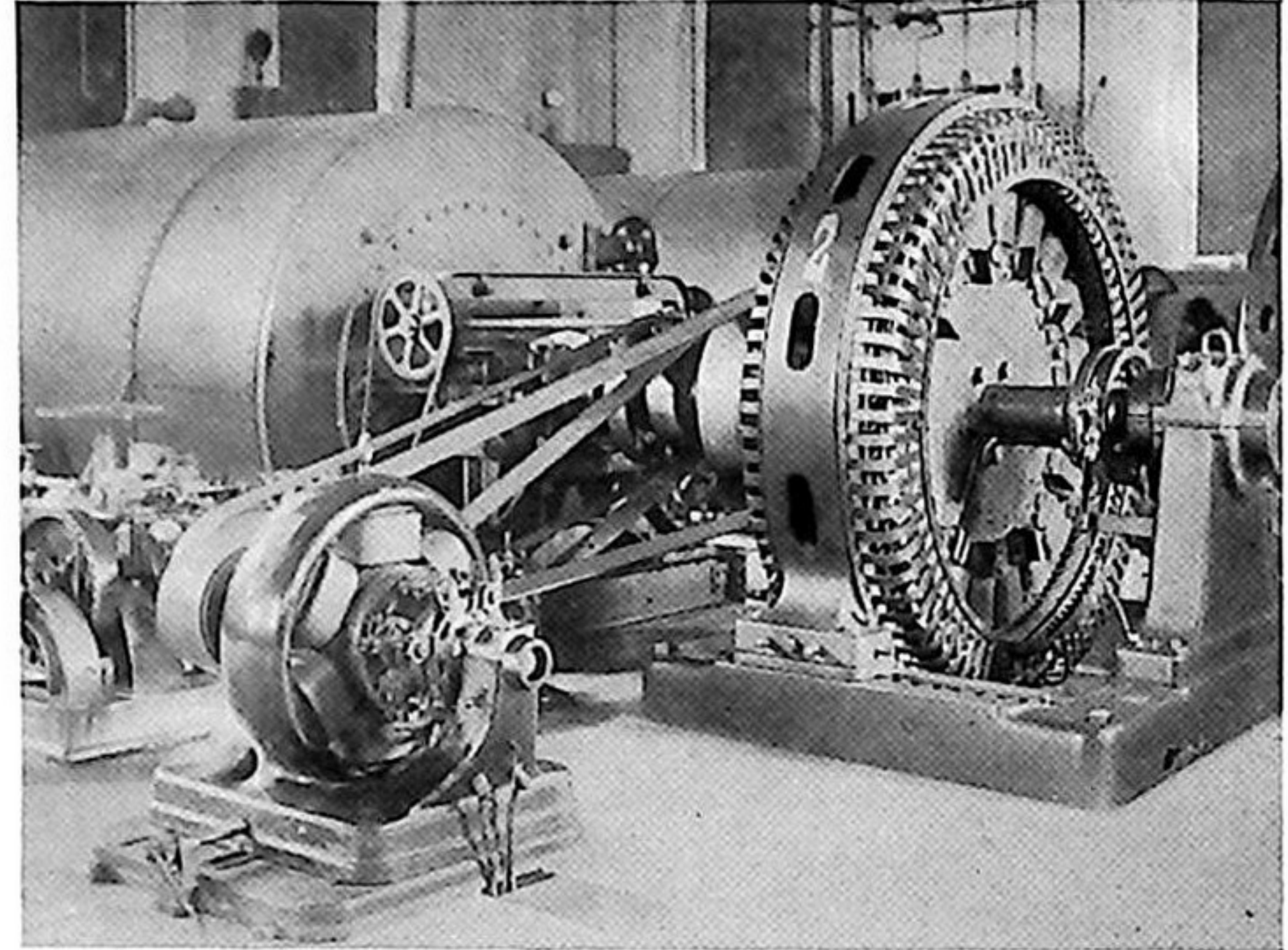


SHAWINIGAN WATER AND POWER COMPANY'S PLANT ON ST. MAURICE RIVER, SHAWINIGAN, QUEBEC, CANADA. Five 15,000 kva., 6,600 volt, 225 rpm. Westinghouse Generators operating under head of 150 feet.

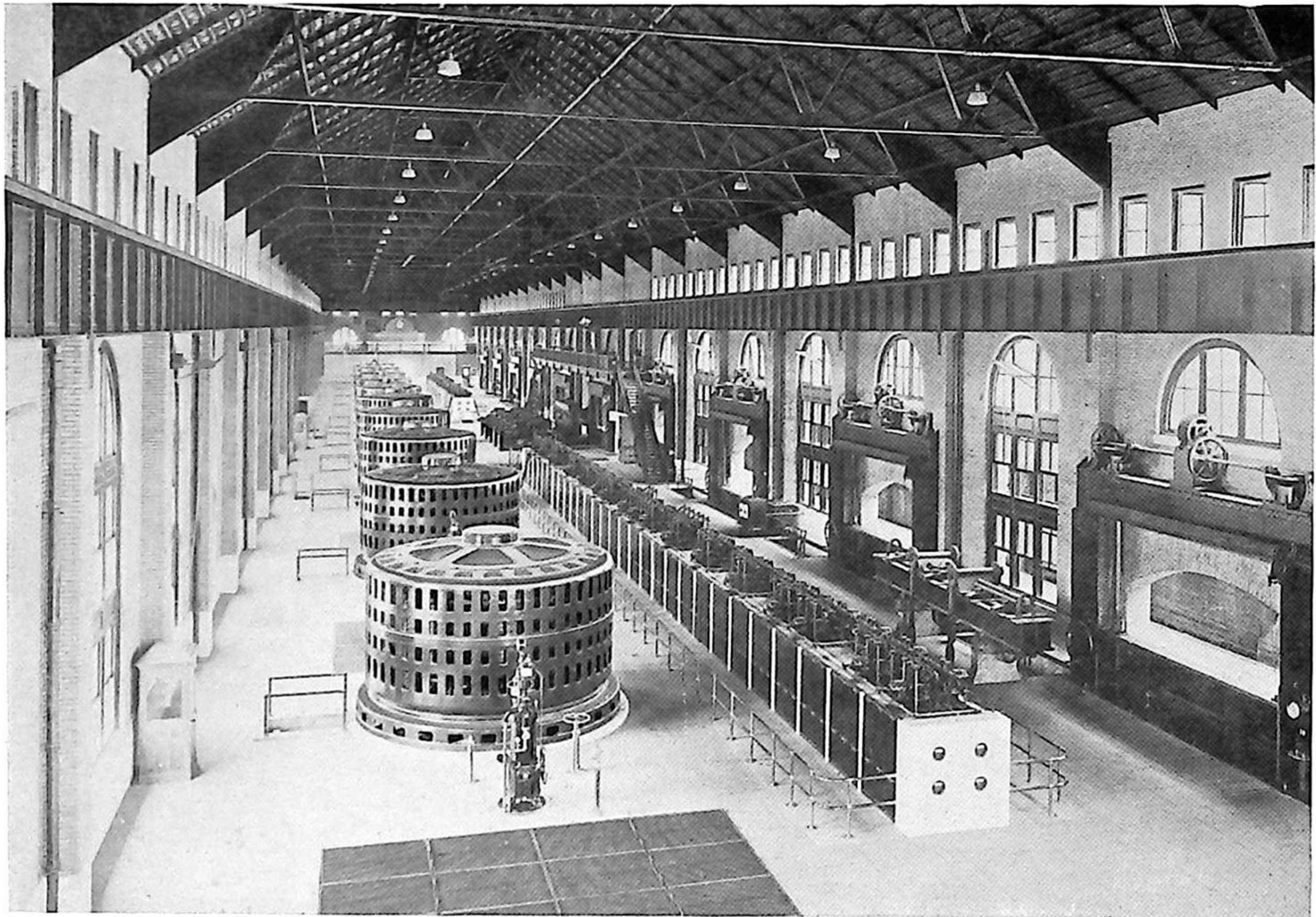
Waterwheel Generators



VIEW OF 600 KVA. UNIT AT KETCHIKAN, ALASKA, showing flywheel between generator and water wheel.

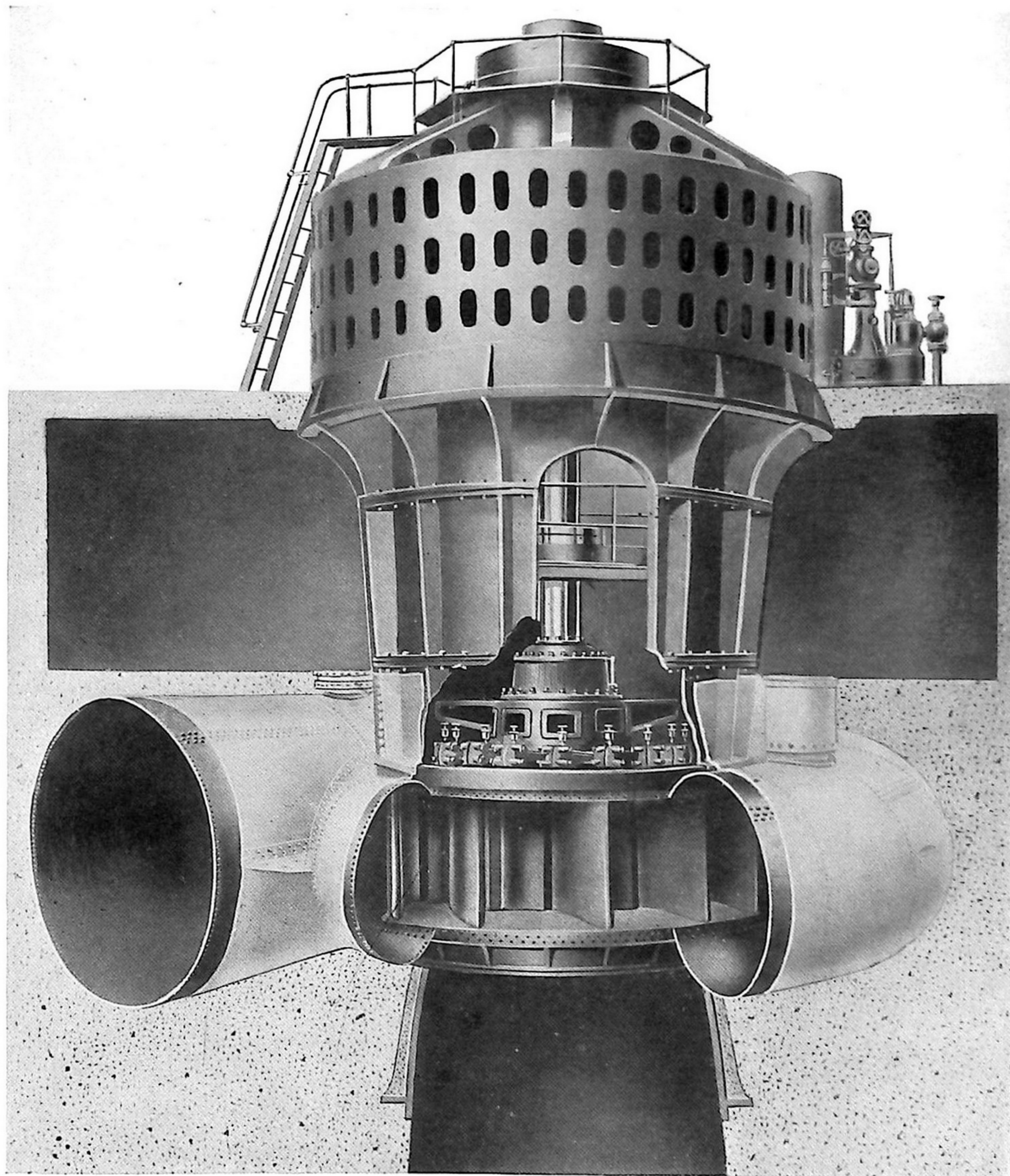


MONUMENT MILLS, HOUSATONIC, MASS. 500 kva. unit, 360 rpm., with belted exciter.



THE NIAGARA FALLS DISTRICT is one of our richest hydroelectric sections. A tremendous amount of power is required by the large industrial and electro-chemical plants nearby, and this can be economically furnished by the several large power houses now installed and in prospect. Five 10,400 kva. vertical Westinghouse Units are shown in the foreground of above view. These units are installed in the Canadian Niagara Power Company's plant. They generate 25 cycle power at 12,000 volts, and run at 250 rpm. A 32,500 kva. Westinghouse Vertical Unit is being installed on the American side of the Falls, and two 45,000 kva. vertical units of Westinghouse manufacture are being built for the new plant near Queenstown, Ontario.

Waterwheel Generators



SECTIONAL VIEW showing a typical arrangement of Vertical Waterwheel and Generator.

Westinghouse Electric & Manufacturing Co.

East Pittsburgh, Pa.



DISTRICT SALES OFFICES

ATLANTA, GA., Candler Bldg., 127 Peachtree Street
 BALTIMORE, MD., Westinghouse Bldg., 121 E. Baltimore Street
 BIRMINGHAM, ALA., Brown-Marx Bldg., First Ave. and 20th Street
 BLUEFIELD, W. VA., Law and Commerce Bldg.
 BOSTON, MASS., Rice Bldg., 10 High Street
 BUFFALO, N. Y., Ellicott Square Bldg., Ellicott Square
 BUTTE, MONT., Montana Electric Co. Bldg., 52 East Broadway
 CHARLESTON, W. VA., Union Trust Bldg.
 CHARLOTTE, N. C., Commercial Bank Bldg., Rooms 409-10-11
 CHATTANOOGA, TENN., Hamilton National Bank Bldg.
 CHICAGO, ILL., Conway Bldg., 111 W. Washington Street
 CINCINNATI, O., Traction Bldg., Fifth and Walnut Streets
 CLEVELAND, O., Swetland Bldg., 1010 Euclid Ave.
 COLUMBUS, O., Interurban Terminal Bldg., 3rd and Rich Sts.
 DALLAS, TEX., Exchange Bldg., Akard and Wood Streets
 DAYTON, O., Riebold Bldg., South Main Street
 DENVER, COLO., Gas and Electric Bldg., 910 Fifteenth Street
 DES MOINES, IOWA, 608 Securities Bldg.
 DETROIT, MICH., Dime Savings Bank Bldg., Fort and Griswold Streets
 DULUTH, MINN., Alworth Bldg.
 EL PASO, TEX., Mills Bldg., Oregon and Mills Streets
 HOUSTON, TEX., Union National Bank Bldg.
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JOPLIN, MO., Miner's Bank Bldg., Room 306
 KANSAS CITY, MO., Orear-Leslie Bldg., 1012 Baltimore Ave.
 LOUISVILLE, KY., Paul Jones Bldg., 312 Fourth Ave.
 LOS ANGELES, CAL., I. N. Van Nuys Bldg., 7th and Spring Sts.
 MEMPHIS, TENN., Exchange Bldg., 6 N. Second Street
 MILWAUKEE, WIS., First National Bank Bldg., 425 E. Water Street
 MINNEAPOLIS, MINN., Met. Life Insurance Bldg., 119-131 S. 3rd Street
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 NEW YORK, N. Y., City Investing Bldg., 165 Broadway
 PHILADELPHIA, PA., Widener Bldg., 1325-1329 Chestnut Street
 PITTSBURGH, PA., Union Bank Bldg., 306 Wood Street
 PORTLAND, ORE., Northwestern Bank Bldg., Broadway and Morrison Streets
 ROCHESTER, N. Y., Chamber of Commerce Bldg., 119 E. Main Street
 ST. LOUIS, MO., 300 N. Broadway
 SALT LAKE CITY, UTAH, Walker Bank Bldg., 2nd, South and Main Streets
 SAN FRANCISCO, CAL., First National Bank Bldg., 1 Montgomery Street
 SEATTLE, WASH., Alaska Bldg., 2nd and Cherry Streets
 SYRACUSE, N. Y., University Bldg.
 TUCSON, ARIZONA
 TOLEDO, O., Ohio Bldg., Madison Ave. and Superior Street
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